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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

THE SOCIETY'S JOURNAL, called *Forestry*, is usually published twice a year, in January and July. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to R. W. V. Palmer, Bannerleigh, Leigh Woods, Bristol. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should begin with a summary which should be factual and convey briefly the content of the article and draw attention to all new information and to the main conclusions. It should be concise and should not normally exceed 200 words. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, The Society of Foresters of Great Britain, 7 Albyn Place, Edinburgh, 2.

SOCIETY'S MEDAL. This may be awarded by the Society to any individual who has rendered eminent services to British forestry. Proposals for the award have to be made in the first instance to the Council by a Member of the Council. The regulations for the award will be found in Vol. XX, pp. 80, 81, and in Rule 11.

[*continued on inside back cover*

R. L. ROBINSON

1883-1952

President of the Society of Foresters of Great Britain

1926, 1927, and 1928

ROY LISTER ROBINSON: AN APPRECIATION

By A. P. LONG

LORD ROBINSON of Kielder Forest and of Adelaide died on 5th September 1952 in his seventieth year and the loss to forestry can scarcely be exaggerated, for he did more than any man to help the cause of forestry in Great Britain and his influence through the medium of the Commonwealth Conference was of outstanding value to forestry in the Commonwealth.

When Robinson came to England from Australia as a Rhodes Scholar he had already acquired an incidental interest in forestry, but at Oxford he came into contact with Sir William Schlich, and it was through him that Robinson became deeply immersed in it. In 1909 when Schlich was asked to recommend a man for the post of Assistant Inspector for Forestry in the Board of Agriculture and Fisheries he recommended Robinson, who accepted the post.

His first duty was to study forestry in this country and to examine the possibilities of extension. This led to a country-wide examination of the growth of trees and resulted in the publication of bulletins on woodlands at Thornthwaite (Cumberland) and Kerry (Montgomeryshire). His early deductions convinced him that the conditions were very favourable to tree growth and the presence of large areas of under-productive land indicated great potentialities for forestry in this country. His arguments were not wholly accepted, but were sufficiently impressive to encourage the government of the day to expand the forestry branch and simultaneously put existing Crown forests and woods under the management of that branch. This led to Robinson's advancement firstly to Inspector, then Superintending Inspector, which post he was occupying at the beginning of World War I. In 1915, when the need for using timber from home resources became apparent, he was in charge for a time of the Timber Supplies Department, then for a short time he went to the Ministry of Munitions, but in 1916 he was back again in forestry as Secretary to the Acland Committee, which resulted in the first comprehensive home forestry report ever produced in this country and in which it is not difficult to discern the major part he played. This report led to the formation in 1918 of the Interim Forest Authority which was succeeded by the Forestry Commission in 1919, of which he was the first Technical Commissioner, and the report itself formed his Bible for future action throughout his career. Later he also became Vice-Chairman and in 1932 Chairman of the Commission in which post he remained until his death. The Second World War showed again the need for using home timber resources and he then set in motion plans which he had already prepared. He took charge of this work until 1942, when he returned to the Commission and became largely responsible for producing the White Papers (Cmd. 6447 and 6500) which led to the great expansion in forestry after the war. He was the only man to attend all six Empire and Commonwealth

Forestry Conferences, taking the Chair in South Africa in 1937 and in England in 1947. It was whilst acting as Britain's chief delegate to the 1952 Conference in Canada that he died.

His gigantic work in forming a Forestry Department from scratch and expanding it to its present proportions is too well known to need detailing, but only a man of exceptional talent could have handled such a task which increased the State Forests from almost nothing to cover an area of more than 1,000 square miles together with all that that entailed. Being himself an indefatigable worker, he demanded a very high standard from all who served under him and he inspired in them all the strictest sense of duty and unflinching loyalty.

The publications previously mentioned give a clue to his early approach to forestry which was essentially mathematical, detailed, precise, and determined by deduction from standing examples. He had great powers of observation and deduction and never departed from this approach and, holding that growing trees were the best indicators of site potentialities, he instituted a widespread system of sample plots. These plots have been greatly increased during the years and have proved very valuable for technical and land-acquisition purposes.

He was very thorough, saw everything, and tried almost every forest operation for himself and was often able to devise improved methods leading to economies. His outlook was severely practical, always demanding the best value for money and the abandonment of anything which savoured of a frill or unnecessary luxury; for instance he was prepared to accept substantially less than 100 per cent. stocking of a plantation if the cost of achieving the last steps of perfection were unduly expensive. Similar maxims were applied to every branch of forestry with great effect and savings. This led to research and trial in both the actual growth of trees and the means of planting and tending, for until he was entirely convinced by successful pilot areas he would not proceed, but once convinced he was prepared to launch out on big-scale effort.

For example, the species to plant and the methods of planting poor-quality lands have been the subjects of research and trial from the early days of the Commission; some problems have yet to be solved, but the investigations have led to improvements in technique such as turf planting, and later, ploughing. Developments in the use of Sitka spruce latterly gave rise to the principle of Pioneer and Successor species which Robinson enunciated and which stimulated the adoption of mixtures on poor land in substitution for pure planting.

The march of time saw his experience broaden from the formation of plantations to the development of the forest as a living organism in its widest sense, not merely as a producer of timber but also as an improved user of poor land with all its economic and sociological implications. The last few months of his official career were spent in inspecting forests from these aspects, and he was convinced not only that the formation of worthwhile forests as timber factories is a practical possibility but that forests are almost the only remedy for depopulation which is proceeding so rapidly in many rural areas of Britain. It is our loss that we shall never see the arguments and final deductions which he had intended to publish on his retirement, for by his nature they would have been forceful and there is

no doubt that the case for forestry on an even larger scale than hitherto would have been greatly strengthened.

A forthright and powerful personality often meets with opposition and criticism, and in this Robinson was not an exception. Of the various aspects of forestry he probably received most criticism in regard to the slow progress of private forestry, the encouragement of which was one of the duties assigned to the Commission on its formation, and his treatment of the question was often misinterpreted as a lack of interest in private forestry. He never failed when opportunity offered to pay handsome tribute to the contributions which privately owned woodlands made during the two wars, and no one was more anxious than he to see that the devastated woods were re-established and all woodlands properly managed. He recognized, however, that because of the lack of a forestry tradition it would take a long time to convince the majority of owners that the production of timber was essential to the life of the country and that the woods must be systematically managed to that end. He held that things which were easily obtained were lightly valued and preferred to see forestry standing securely on its own feet rather than being heavily subsidized. For a long time he was not convinced that private forestry had reached the stage which he desired and he felt the best interests of the public would be served by rapid development of State forests which, he held, gave the best value for the small amount of money which was available. But, towards the end of the Second War, when he felt that public opinion was rallying in the direction he aimed at, he developed the Dedication Scheme which was agreed by all after some modification and which he felt gave proper security to the State as well as providing reasonable encouragement to landowners. Towards ensuring proper management as economically as possible he introduced schemes of free technical advice and courses in forestry for landowners, agents, foresters, and others which have been well attended.

His relations with the Timber Trade and other organizations were of the friendliest, and he supported warmly the various methods adopted from time to time to increase a joint interest in all forestry matters affecting industry, amenity interests, scientific bodies, and the public at large. He also initiated the formation of National Forest Parks for public recreation and enjoyment.

He took a large part in forming the Society of Foresters of Great Britain. He was President of the Society in 1926, 1927, and 1928, and he was the first to receive its Gold Medal.

Any survey of Robinson's work, however brief, shows the calibre of the man. Forestry was his one prevailing interest. The power which came to him with his honours of knighthood in 1932 and a peerage in 1947 was devoted to its advancement and forestry has lost its most important advocate. His staff will mourn the passing of a revered Chief and the country will pay tribute to his memory. But there will remain his outstanding example, whilst the forests he created and other forests yet to arise on the foundations he laid will endure as a monument for ever.

JOHN DONALD SUTHERLAND: AN APPRECIATION

By H. M. STEVEN

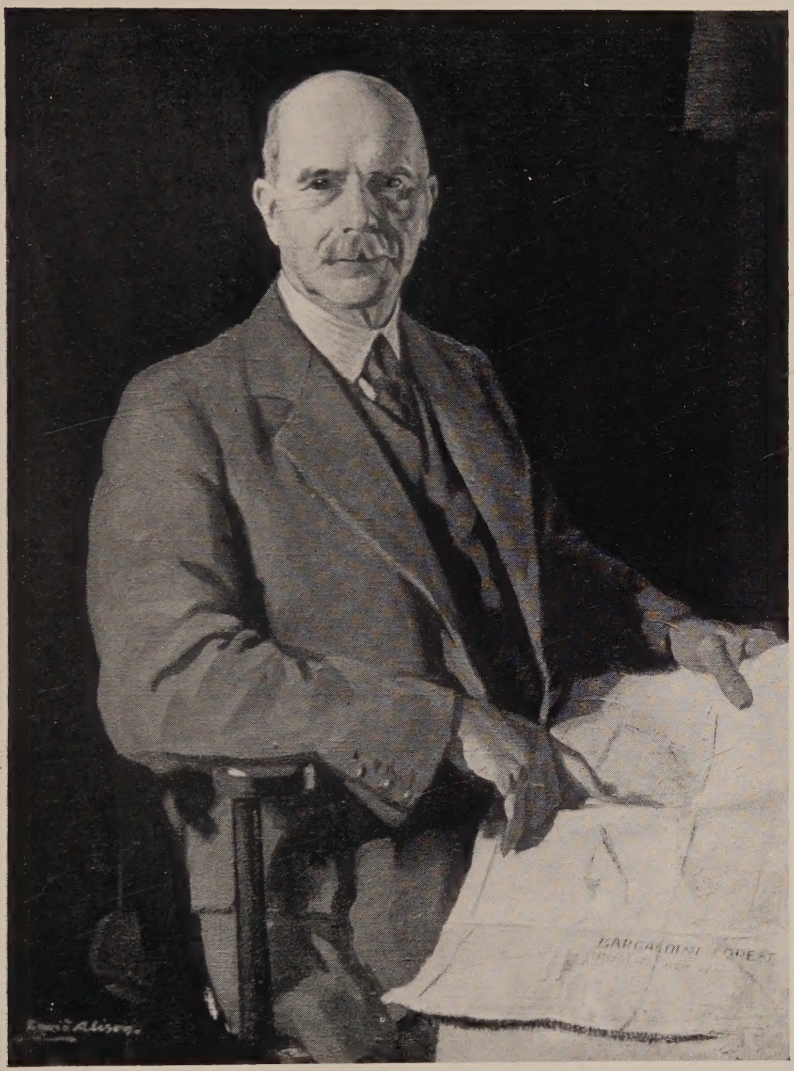
SIR JOHN SUTHERLAND, C.B.E., LL.D., F.R.S.E., died on 6th August in Edinburgh. For over 50 years he took a leading part in the renaissance of forestry in the British Isles, particularly in Scotland. No other man had a greater part in founding and guiding the early steps of the Society of Foresters of Great Britain, and tributes were paid to him by the late Lord Robinson and others at the Semi-Jubilee dinner in Oxford in 1951. He was President of the Society in 1929 and 1930.

Sutherland was born in Inverness on 10th November 1865, and his Highland background, and the realization of what forestry might be able to do in repopulating the glens, might have been one reason for his lifelong devotion to forestry. He was educated at Inverness Academy and Edinburgh University, where he graduated in Law in 1892. He became a partner in a firm of solicitors in Oban, and he first showed his interest in forestry in connexion with the management of private estates in that district. On the formation of the Board (now Department) of Agriculture for Scotland in 1912, he was appointed a member and was Commissioner for Small Holdings. One of his duties was to initiate the forestry works of the Board. In 1916 he became executive officer of the Home Grown Timber Committee in Scotland and Chairman of the Scottish Advisory Committee on Home Supplies. In 1917 he went to France as Assistant Director of Forestry and played an important part in organizing the production of timber supplies for the British forces from French forests.

He was a member of the Acland Committee whose recommendations led to the setting up of the Forestry Commission in 1919, and he was then chosen for the post of Assistant Commissioner in Scotland, which he held until 1934. Thus he was responsible for the initiation of the work of the Forestry Commission in Scotland and for its development over a long period. His administrative capacity, quality of leadership, and his many personal contacts have contributed much to the development of Scottish forestry since 1919. He became a Forestry Commissioner in 1935 and retired officially in 1942, although he continued thereafter to attend meetings of the Commission and thus make his great experience available to his colleagues.

In 1950 the name of 'Sutherland's Grove' was given to a clump of Douglas firs at Barcaldine forest in Argyll in recognition of his work for forestry; he was associated with Barcaldine both before and after its acquisition by the State. When members of the Society visited this Grove during its annual excursion in 1950, they sent a message of greeting to him.

John Sutherland was not only a leader in his chosen field, but was also a man who in outstanding degree inspired affection and loyalty. He was always ready to help and many owe much to his kindness and generosity and will cherish his memory.



JOHN D. SUTHERLAND

1865-1952

President of the Society of Foresters of Great Britain

1929 and 1930

THE IMPROVEMENT OF WOODLANDS IN DUMFRIES AND GALLOWAY

By M. J. PENISTAN

(*Forestry Commission*)

SUMMARY

The history of the woodlands is outlined and a brief account given of their development up to 1945. The paper then describes how rehabilitation has proceeded since by co-operation between owners, foresters, and the Forestry Commission, and what modifications of silvicultural practice have been adopted to overtake the arrears of management resulting from depression before the Second World War and from extensive felling during the war itself.

THE counties of Dumfries and Wigtown and the Stewartry of Kirkcudbright can conveniently be divided into (*a*) the steep-sided higher Silurian and Ordovician hills of the Southern Uplands, with shallow mineral soils on the higher slopes up to the tree line (1,200–1,500 feet), and with loamy boulder clays and moraines on the valley bottoms. Their foothills, with gentle slopes, carry much boulder clay and rarer shallow soils on outcrops, with peat formation general on level ground. (*b*) The granite and hard auriole rocks of the Galloway highlands, with much outcrop and broken terrain, screes, moraines, and many basins filled with boulder clay, peat, and water. Their foothills with more even slopes have boulder clay in small pockets between outcrops of Silurian rocks. (*c*) The low valleys, some geologically ancient, as in Nithsdale and Annandale, the low carselands and other river valleys, all drift covered with few outcrops of the underlying rocks, but with the boulder clays masked by extensive fluvio-glacial gravels and alluvial terraces, and extensive level peat bogs or flows.

The climate is mild and wet. Annual rainfall increases from 35 inches at sea-level to 90 inches in the Galloway highlands and 60–80 inches in the Southern Uplands. There are no outstandingly dry months. Winters are rarely severe and, apart from the highest hills above tree limit, snow does not lie long. *Pinus insignis* grows satisfactorily in the mild climate on the sheltered raised beaches of Luce and Wigtown Bay. Spring and autumn frosts are common and cause serious damage, especially the spring frosts of May which catch many trees just when leading shoots are developing. Gales are frequent, but usually from the south-west. The great danger to trees is from high winds with heavy rain or wet snow from the north-east and north-west. One or two such gales occur annually.

The great expanse of boulder clay causes drainage to be impeded and gley horizons are common in the heavier drifts. The majority of soils are brown earths, and degradation is limited apart from local areas in the low hills of the Galloway granite where leaching is marked in the Dalbeattie area. Peat occurs in all areas where drainage is impeded. The factors most affecting forest management are the need to drain the retentive soils in a wet climate—almost all soils need drainage—the occasional severe winds which are particularly damaging on the

ill-drained soils, and the spring frosts. As elsewhere in Britain, the rabbit puts a severe limit on silvicultural practice, and roe-deer are present in fair numbers in the Stewartry.

The natural climax forest was oakwood (*Quercus*), with associated sub-climaxes of ash (*Fraxinus*), birch (*Betula*), and alder (*Alnus*). Scots pine (*Pinus sylvestris* L.) does not appear to have occurred naturally after Boreal times. The Forest of Ettrick occupied the forest areas of the Southern Uplands, and the alder, hazel (*Corylus*), and juniper areas in Eskdale are probably the last survivors, as are the scattered junipers of the ancient Wood of Keir in Nithsdale. Sessile oaks (*Quercus petraea* Liebl.) are found especially in Galloway and oak still remains the most extensive woodland species and probably the least affected by disease and best related to the environment. The existing oakwoods developed from the great era of land improvement begun in the early eighteenth century. The plantations and policies then laid out had the 'English' oak (*Q. robur* L.) as the main species with beech (*Fagus*), elm (*Ulmus*), lime (*Tilia*), ash, sycamore (*Acer pseudoplatanus* L.), and Scots pine, Norway spruce (*Picea abies* Karst.), European silver fir (*Abies alba* Mill.), and the newly imported European larch (*Larix decidua* Mill.). Oak on steeper rocky hills and banks was worked as coppice, and very much of the oak now found in Galloway apart from the planting immediately round big houses has developed from it. English pedunculate oak is now generally distributed and was probably used to replace worn coppice stools of native oak.

Once the improving lairds had planned their agricultural ground and established their farms, had planted their parks and policy woods and consolidated the coppice areas, attention was paid to relatively extensive plantations on the less easily improved land, largely on the foothill sites and the edges of drained peat bogs. Scots pine was at first chiefly used with an increasing amount of European larch, much of it on felled oakwoods, which may account for the excellence of the stands remaining today. Japanese larch (*Larix leptolepis* Gord.) was successfully introduced; the early plantings at Lochinch in Wigtownshire and at Eskdale in Dumfriesshire were of excellent strain. Pure plantations of exotics do not, however, appear on any large scale until after 1910, and the earlier crops which survived the war fellings are of what became known as the forester's or nurseryman's mixture—equal proportions of Scots pine, Norway spruce, and European larch and occasionally beech, oak, or sycamore as a hardwood ingredient.

It is a feature of the area that interest in forestry continued from the days of the improvers; there was no very marked neglect in favour of game preservation, though the foresters' activities were seriously limited in the nesting season, thinning suffered, and rabbit populations increased first in warrens but later generally. In 1910 Nisbet drafted the first Shambellie Working Plan and at the same time Mr. J. H. Milne-Home, now Sir John Milne-Home, compiled the plans for the Buccleuch woodlands in Eskdale. The basic ideas were those of the German economists, Faustmann and Pressler, and were put into practice just when continental foresters were finally abandoning or modifying them. Extensive new plantations were begun just before 1914 on Eskdale Estate, on peat-covered boulder clay largely of pure plantings of Sitka and Norway spruce and of Japanese

larch on the mineral soils. They were completed in 1926 and the first areas clear felled in the last stages of the Second World War. There were also noteworthy new afforestations on the foothills above Annandale by the Castlemilk Estates, whose woodlands are still under conversion from game coverts to pure forestry subjects.

The period between the wars was not a particularly encouraging one for private forestry. Good progress in the majority of cases was made with replanting, by all who could afford it. Less than 1 per cent. of the new planting was broadleaved, and much of the remainder pure planting with fast-growing conifers. There was, however, a poor demand for thinnings and the plantations made before the First War were as a result largely neglected. A great proportion of the badly neglected woods was cleared in 1939–45, as were the remains of the best timber. The efforts of a group of landowners and agents in Kirkcudbright to carry out co-operative marketing of thinnings must, however, be recorded, and with the assistance of Mr. Bruce Urquhart, then working with Messrs. Mould and Bloomer, they were able to prepare and market conifer thinnings as pit-props. At this time, too, new working plans were put into force by Messrs. J. Maxwell Macdonald at Kirkennan and Bruce Urquhart at Cardoness, Kirkdale, and Cairnsmore.

The census figures for 1947–9 given in Table I show the extent of the felled woodlands both as a result of the Second War fellings and of First War and later fellings. The relatively small area of devastated woodland is due to the close utilization practised by the Scottish timber trade by the establishment of temporary saw-mills in felling areas, and also to the interest in forestry of a clear-felling and replanting system which has through usage resulted in a clearing of less valuable as well as easily saleable produce. (Even if woodland is not to be replanted through lack of funds or change of policy it is still normally properly cleared as it will be grazed.) The progressive decrease in the area of hardwood planting is clearly shown in the figures of productive woodland, and the corresponding increase in conifers is notable. What is not clear is that the older woods are largely mixed conifer and hardwood, and hardwoods of a number of species, while the younger woods are almost entirely coniferous and consist of pure stands of single species. The distribution of age classes between broadleaved conifer and mixed woods is given in the Table.

At the beginning of the programme of improvement, woodland owners not only were faced by the need to bring into full production the unproductive acreages of woodlands shown in Table I, but they had to take in hand the improvement of the stocked woodlands. These were not in a very good way even on the best managed estates. There had been a grave shortage of labour during the war, when forestry operations had primarily dealt with timber production and maintenance of existing fixed equipment. The economic conditions before the war had made the marketing of normal produce extremely difficult, and the skilled supervision available had been, and still was, very limited, so that while most woodlands were in the care of excellent practical foremen, foresters, and estate maintenance men, there were relatively few head foresters capable of woodland management or of taking new or unusual measures to deal with the state the woodlands were now in.

TABLE I. *Distribution of productive woodlands in acres by age classes and categories and of unproductive woodlands in acres in Dumfries and Galloway from 1924 and 1947–9 Census*

(Note: 1924 Census includes woods down to 2 acres, 1947–9 to 5 acres)

Census years	Type	Productive									Unproductive				Grand total
		1–20 years	21–40 years	41–60 years	61–80 years	81–120 years	Over 120 years	.. Uneven aged[1]	Total	Coppice	Scrub	Devastated	Felled to 1939	Felled after 1939	
1924	Conifers	6,766	6,104	8,192		365		..	21,427	..	6,829	10,545		..	66,501[2]
	Mixed	197	915	3,525		840		..	5,477	..					
	Hardwoods	115	623	6,119		6,109		..	12,966	1,447					
	Total	7,078	7,642	17,836		7,314		..	39,870	1,447	6,829	10,545		..	
1947–9	Conifers	6,606	5,385	1,444	504	497	91	300	14,827	..	53	379	6,058	8,844	55,299
	Mixed	54	156	379	407	968	367	1,582	3,913	..	—	—			
	Hardwoods	55	226	530	1,353	3,656	2,330	3,550	11,700	236[3]	8,707	582			
	Total	6,715	5,767	2,353	2,264	5,121	2,788	5,432	30,440	236	8,760	961	6,058	8,844	55,299

[1] Not classed separately in 1924. [2] Includes 7,810 acres classed as uneconomic. [3] All coppice as in Kirkcudbright.

TABLE II. *Summarized distribution of major species in scrub woodlands and devastated woodlands in Dumfries and Galloway in 1947–9*

	Scrub					Devastated
	Oak	Birch	Other broad-leaved*	Conifer	Total	Total
Dumfries . . .	618	2,367	469	..	3,454	749
Kirkcudbright . .	1,415	1,923	594	31	3,963	89
Wigtown . . .	49	621	651	22	1,343	123
Total . . .	2,082	4,911	1,714	53	8,760	961

* Main species: *Dumfries*, Alder; *Kirkcudbright*, Ash; *Wigtown*, Ash.

Those undertaking the improvement of their woodlands had to face (*a*) a very considerable area felled in 1939–45, (*b*) an area almost as large as this not replanted after earlier fellings, but generally fairly clean, (*c*) a large area of hardwood scrub, often run-down coppice but also natural regrowth after felling of hazel, birch, and ash and sycamore stool shoots, (*d*) very fast-growing young woods often pure and all in need of thinning, (*e*) older more mixed conifer woods, the remains of those felled in the wars, and (*f*) a very considerable mass of older woodland predominantly hardwood, from which the conifer admixture had been cut, or in which the conifer admixture was becoming over-mature, and in the case of the oldest age class from which many of the fine stems which had held their value between the wars had been removed. This state of affairs was, of course, common to most woodland areas of Britain.

There were in the area a number of timber merchants who had built up plant and labour during the war, and who had as a result of the encouragement of a policy of thinning in the last year of the war some experience of thinning work, a number of men returned from the forces, and a further number of prisoners of war awaiting repatriation. The demand for timber remained. There were, too, examples of woodland on the Eskdale and Liddesdale Estates which had been under continued working-plan management for 35 years, and in which rabbit control had been effective for the same period so that netting was unnecessary and small local planting and regeneration practised. Shambellie Estate had followed their plan and revised it periodically since 1910 and there were three small estates all in good and successful condition managed by a consultant forester, while others were able to pool their resources and share markets through a common estate office. (Munches, Kirkennan, Senwick, and Ardwell.) There had been close and successful co-operation with the Forestry Commission before the Dedication Scheme was launched, so that there was no official ice to break when the Conservator and his private woodlands staff began to discuss the improvement of private woodlands with their owners, and there were examples of the type of management the dedication would entail already in action and examples of successful management by the co-ordinating body of the forestry consultants, the Co-operative Forestry Society (Scotland) Ltd., through their technical officer.

Owners interested in their woodlands were thus in a favourable position at the onset of the drive to improve management and restock the unproductive areas, and work on the preparation of plans of operations began early. What is as important, the actual forestry work was immediately put in hand. The rise in timber prices following de-control, the market for poorer hardwoods and for firewood were taken advantage of to the full, as were the thinning grants. The fact that some owners were resolutely against the Dedication Scheme did not deter them from actively restocking and improving their woods. Those who were unable to replant were generally very willing to negotiate for acquisition by the Forestry Commission. A very large proportion of the Dumfriesshire woods are now coming under working-plan management. In Galloway, where a greater proportion of woodland is in single-farm ownership, there is a good area of poorly stocked

woodland still to be tackled, but as the advantages of good management are increasingly demonstrated, the rest will continue to come in.

There was a general realization that the financing of forestry operations from further clear fellings was out of the question on most estates in view of the large areas to replant. There was at the start a shortage of plants for restocking and a very limited choice of species. The aim of a series of age gradations of fast-growing conifers managed on a financial rotation, of crops of serried uniformity was acknowledged (often unconsciously) to be impractical. Labour costs had so risen that many of the elaborate methods of preparation of the ground for planting and of complete weeding were quite uneconomic and more flexible methods of working taking every advantage of local conditions were adopted. A summary of treatments of different crops and categories of woodland is outlined below.

Restocking of woodlands. There have been remarkably few new developments in planting technique. The mechanical developments of preparation of ground of the Forestry Commission's afforestation programme are not applicable to the restocking of recently felled woodlands. The shortage of plants has, however, led to the general adoption of wider planting distances, which is often in the more sheltered places in this rapid-growth climate well justified. Sir John Milne-Home has raised very satisfactory stands of Sitka spruce at 7 feet and 8 feet spacing; the branch development is greater in the lower portions of the stem, but brashing removes most of these branches. While plants were short and a very large area of woodland lay unproductive, planting distances were generally increased, not often to 8 feet by 8 feet, but the fastest growing conifers, Japanese larch, Sitka spruce (*Picea sitchensis* Carr.), Douglas fir (*Pseudotsuga taxifolia* Brit.), were commonly planted at 6 feet by 6 feet, occasionally at 7 feet by 7 feet, and the remaining conifers at 5 feet by 5 feet, occasionally at 6 feet by 6 feet. A second saving of plants, and a very sound silvicultural advance, has been obtained by retaining all usable natural growth, usually hardwood, when areas are restocked. It had previously been general to cut all ground to be planted clean on the grounds that uniformity was above all things desirable and that hardwood and occasional naturally regenerated conifers were uneconomic. There is, however, now a general appreciation of the value of a proportion of hardwood in crops, not only ecologically, but as a break at which to hold windblows which have proved so common on the majority of even-aged sites. By retaining advance growth of birch, sycamore, ash, and alder it has been possible to retain some degree of forest conditions to secure quick establishment. There is a considerable increase in the planting in mixture of hardwoods. Mixed conifer crops are also now more used, both to leaven the extensive pure spruce plantations and to obtain more stable pole crops and manageable thinning stands. The Co-operative Forestry Society have encouraged discrimination in the use of planting stock of proved good and suitable origins. The old practice of meticulous cleaning up and burning of sites before planting has been reduced to the minimum, as has the degree of weeding.

Apart from the almost traditional dearth of rabbits on the Buccleuch estates there has as yet been little successful rabbit control and wire-netting is almost invariably used. The importance of forestry has increased *vis-à-vis* game

preservation, however, and some head foresters control rabbit killing within the fenced plantations with good results. Comlongon Estates in Dumfriesshire have successfully invested rabbit control in the main woodland block in the head forester who now uses no netting. It has been a practice for some time now for the killing of rabbits on Castlemilk Estate to be freely available to the public, who may not, however, use traps, dogs or guns, and it is now probable that some netting could be dispensed with. In Galloway the rabbit is very much more populous and no special control measures outside the Forestry Commission woods have been taken. Mention should be made of the use of deterrent oils successfully by the Co-operative Forestry Society in woods they manage where special trees are being grown and deer and goat damage is extensive. A glimpse of the improved rabbit-free conditions in which future British foresters will work was afforded by the very heavy depletion in rabbit stocks brought about by the severe winter of 1947. The population of this pest has now recovered.

The treatment of scrub and devastated areas. The conversion of oak coppice or semi-natural woodland has gone on for at least a century. Either the coppice was thinned out, stored, and by a single or progressive reduction of the number of shoots per stool was changed to high forest. This was successful where the coppice was vigorous and many of the oakwoods of the present day typified by those at Capenoch have arisen in this manner. Or the coppice was clear felled and conifers planted. The first conifers used were Scots pine and more often European larch, and fine crops such as are found at Shambellie, Munches, and Kirkennan have developed. Latterly Douglas fir and Japanese larch, both of which start growth quickly and suppress the coppice shoots, have been used to produce pure conifer woods. The oak shoots linger on under Scots pine, just as does ash under Douglas fir often to form part of the mature crops producing a mixed aspect which tends in the pine to preserve the ecological balance and in the larch to reduce by isolation the extent of the larch diseases. The oak scrub recorded in 1947–9 was either oak coppice of moderate to poor form (the best former coppice was recorded as such) or stored coppices which have not succeeded. Table II shows that oak scrub is most commonly met in Kirkcudbright. It occurs in the foothills of the Galloway Hills, on steep well-drained slopes too rough or sloping to convert readily to agriculture. They yield a low increment, but are often so extensive as to make clear felling and replanting out of the question. Much work has been done in oak coppices by the Co-operative Forestry Society under working plans made by Bruce Urquhart for the estates of Cairnsmore, Cardoness, Kirkdale, and Gilchristland. There was no good market for oak poles prior to 1939 and conversion took the form of coupes for firewood, retaining all trees capable of making timber and under planting with Norway spruce for Christmas trees. A demand for pickets during the war enabled considerable areas to be clear felled and planted with Douglas fir and Japanese larch, and after the war the increased market for firewood and for hardwood mining timber has enabled conversion to go on systematically. The scrub areas are cleared in succession to produce chockwood and firewood and are planted with suppressive conifers. All former oak coppices are now classified either as productive woods which, if thinned, will yield reasonable high forest or

as unproductive scrub. Earlier treatment by thinning and interplanting with tolerant conifers has taken place at Kirkennan as well as the more general storing or clear felling and planting. Other estates attempted to profit from good prices by converting coppices to coppice with standards. These have proved unsatisfactory as the standards reserved were poor stems, the coppice stools exhausted and badly cut, and the resulting shoots have been badly damaged by rabbits and grazing stock.

The remaining scrub areas are the thickets arising from colonization of felled woodlands or margins of peat mosses. There is relatively little good birch left. Much of the better has disappeared or been badly damaged by fire and grazing. The birch of Parton in Kirkcudbright is both very large and straight and fine stems can be seen at Laurieston. There was fine birch cut in the Thornhill and Annandale area during the war—clean, cylindrical, and of good size. Treatment of it and alder by thinning and interplanting were necessary. It is notable that, where rabbits are controlled, oak seedlings often appear plentifully in birch. Ash often occurs in dense drifts which can be thinned out and similar stands of sycamore have been successfully treated at Cavens. In general a considerable proportion of scrub is found on inspection to be capable of marketable timber production and this is retained on treatment. In all cases as much erect growth as possible is retained to reduce the number of plants for restocking and to shelter them.

Pole crops—thinnings. The thinning of some 7,000 acres of fast-growing conifers and mixed woods had had little attention until 1945, when the emphasis on pitwood production turned from clear felling to thinning. The alternative was to clear fell further areas of immature timber. The sale of standing thinnings which had for some time been unpopular with head foresters was embarked on with some urgency. The traditional degree of thinning had been light, based on treatment practised in the dense pinewoods of Morayshire and Strathspey. Those stands due to be thinned before the war were heavily overstocked with trees, the crowns of which were reduced to relative subdominance or suppression when compared with stands normally thinned. This crown reduction was particularly serious with intolerant species such as Sitka spruce and Japanese larch, and there was little understanding of the treatment of these species and of the other fast-growing exotic conifers. The need for a degree of thinning heavy enough to maintain the crown lengths to at least one-third of the total height, and if possible more, was demonstrated by comparisons with Forestry Commission sample plots, a number of which were in private woodlands. There were exceptions as the Japanese larch stands on Cairnsmore show, but generally underthinning was practised. By dint of instruction, Forestry Society excursions, thinning competitions and by publicizing the success of the bold thinnings by Messrs. Bruce Urquhart and T. W. Dalgleish at Dalswinton and the fine example set by Commander Maxwell, which was enthusiastically followed by the majority of forest owners and managers, a more realistic grade of thinning was adopted. The Forestry Commission thinning grant provided the final stimulus and the care of pole-crop stands is now very well understood. It is also clear to all

who have drawn up plans of work and who have seriously compared the relative health of different age classes and mixtures that the mixed Scots pine, Norway spruce, and European larch plantations of the early 1900's have formed more stable and healthier stands than their pure-planted successors. It has also been clearly demonstrated to general satisfaction that windblow has been no greater in thinned than in unthinned woods, and that the damage occurs in areas incompletely drained, except where hurricane gusts strike and cause snapping of stems rather than uprooting.

Old woodlands. While large areas of felled woodland remain to be restocked, it is good policy to limit clear felling. Late improvement fellings concentrated on the poorer hardwood stems which until very lately have been readily saleable, and on those conifers which are going back rapidly. The majority of the old woods are hardwood or mixed (Table I), and clear felling has in many cases been avoided. It has often been possible to combine the improvement felling with the provision of light to natural regeneration and advance growth, and this work has been particularly encouraged and led by the Duke of Buccleuch, personally in the Buccleuch Estates woods at Langholm and Thornhill, and by the Co-operative Forestry Society in the woods under its control. A great opportunism in the management of these old mixed woods has already been shown generally, and mixed forestry is now established as a reputable treatment for the more stable older woodland. An account of the treatment of some of the mixed woods of Dumfriesshire has recently been published (1).

To conclude, it has been possible to press on with improvement in Dumfries and Galloway as a result of the live tradition of good management of woods, the existence of examples of working plans and rabbit control in action, and the willingness of the forest managers to advise all who consulted them. A sympathetic understanding between Forestry Commission staff and private woodland owners and their staffs, which existed before the Dedication Scheme was launched, and a degree of forest sense in the whole countryside made the work of launching rehabilitation much easier. A very active region of the Royal Scottish Forestry Society has enabled the woodland owners, their head foresters and junior staff, and officials of the Forestry Commission to take part in full and searching discussion not only of silvicultural matters but of all facets of woodland management. The writer whose good fortune it has been to act as private woodlands officer in the region reviewed thanks all those woodland owners, factors, and head foresters who have so courteously and patiently allowed him to gain a close knowledge of their woods and of their experience. Unpublished figures from the Census of Woodlands statistics for 1947–9 have been used to illustrate this article, which is published with the permission of H.M. Forestry Commissioners.

LITERATURE REFERENCE

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THIRTY YEARS' DEVELOPMENT OF AFFORESTATION TECHNIQUES ON DIFFICULT GROUND TYPES IN SOUTH-WEST SCOTLAND

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SUMMARY

The development of ploughing, draining, planting, and the use of turfs and of phosphate is considered in detail for each of two main types. For *Molinia* lands, the 1952 technique secures adequate drainage and a very considerable turnover of turf, and here the spruces *Picea abies* Karst. and *P. sitchensis* Carr. remain the first choice. For *Calluna* lands, the development of methods and the choice of species is more difficult. The spruces refuse to grow pure and unnursed on the poorer *Calluna* types and the use of Scots pine (*Pinus sylvestris* L.), *P. contorta* Doug., the Mountain pine (*P. uncinata* Ramond), Japanese larch (*Larix leptolepis* Gord.), and Douglas fir (*Pseudotsuga taxifolia* Brit.) is discussed. The main requirements for successful afforestation of these ground types are summarized.

GROUND for first planting may be conveniently separated into *easy* ground on which plantings by simple traditional methods such as direct notching and pitting readily become established, and *difficult* ground on which these simple processes would result in early failure or at best in many years of melancholy check. We are interested in the *easy* types of ground only to point out that they differ most markedly from the *difficult* by having soils which are almost invariably permeable and naturally well drained, and by supporting a grass, herb, or shrub vegetation which has neither a felted turf nor a matted rooting layer to impede seriously the movement of either air or water.

The first State forests in south-west Scotland had some tracts of easy ground over much of which notch planted trees were soon established. These are now fine plantations which have already yielded several thinnings. Like most really extensive areas acquired for State planting, however, a high proportion of the land was decidedly difficult, and, as a result, there were very heavy failures in compartments which were notch planted in the early twenties. The fact that the plants did not die immediately but often lingered on in a state of mere existence tended both to delay recognition that something was wrong and to make repair more difficult. Broadly speaking the failures occurred mainly on two types of difficult ground—*white* or *Molinia* land on 6 to 20 inches of wet peat, and *black* or *Calluna* land most often with a thin 2- to 8-inch skin of tough peat over compacted glacial debris. The white lands frequently had cotton grass (*Eriophorum*) and other bog plants among the *Molinia*, while the black lands had *Scirpus*, among other things, in greater or lesser degree according to the time which had elapsed since the last muirburn.

White lands are typical of the border hills with their relatively basic rocks, especially towards the wetter west. The first stretch to be acquired by the State

was Tweedenhead in Liddesdale, the forest now known as Newcastleton. That was in 1921. Five miles across the valley to the south-west the late Duke of Buccleuch had established some 300 acres of plantation by this time on very similar land which is known as Moorburnhead. This work had begun in 1913 and practically the whole area was 'L' notch planted. As might be expected the trees grew well from the start on the better ground, but on the *Molinia* peat, establishment was very slow despite good planting stock and much more surface draining than was allowed to begin with at Newcastleton. Most of the plants used at Newcastleton Forest in the first 2 years were undersized; this is not surprising considering the sudden demand for tree plants which the new State schemes required. Practically no new draining was carried out in the beginning, only some cleaning of old sheep drains being allowed. Most of these ran straight up and down the hill and therefore cut off little of the surface water. The year 1923 saw the first actual new draining for planting. It was restricted to two compartments only, but the importance of adequate drainage was beginning to be realized. Results of the first year's notch planting were so disappointing that in the second (1922) screefing was introduced in an attempt to limit vegetation competition. At Newcastleton, however, screefing did not amount to the usual scraping of the turf with an adze-like tool but was effected by a so-called rail-spade with which a turf about 9 inches long by 6 inches broad by 3 inches deep was removed before the plant was notched into the screef bottom. Despite much bigger and better sized planting stock, this attempt to help the young plants was a complete failure, many plants being drowned in the water which collected in the deep screefs. Methods of dealing with this defect were tried unsuccessfully and eventually it was ordained that screefing should cease. Notching without any screef was re-employed in 1925 and 1926 over almost the whole of the new ground.

In the winter of 1926–7 a special investigation into the conditions at Newcastleton and Moorburnhead was organized. The party included the Technical Commissioner (later Lord Robinson), the then Chairman (Lord Lovat), and several research officers. Having H. M. Steven's 1923 'Root Form on Peat' report[1] and subsequent turf-planting work by M. L. Anderson very much in mind, most members of the investigating mission were convinced that some method to achieve shallow planting of the roots or, better still, some form of turf planting, ought to be adopted, and several members were determined in their belief that far more surface draining was required. To support their views they pointed to the much better growth of such few trees as happened to have been planted on drainside turfs or spoil from the drains up to that time in the forest. Now the forester, J. F. Macintyre, who is still in charge of Newcastleton, had been trained at Glencoe, where the Belgian form of turfing had been introduced on some bad bogs round about 1912 by the famous forester Dr. John Nisbet. It would be strange, therefore, if J. F. Macintyre had not tried a little turf planting in the forest, but whether for reasons of cost or not, very little indeed seems to have been done. According to records half an acre of Belgian turfing was to be prepared for the 1925 plantation. This is strangely little in view of the fact that 120 acres of

[1] Circulated within the Forestry Commission only.

the planting ground that year were drained at 7- to 8-yard intervals. The visitors were, however, shown some turfs which had been cut out of individual holes in earlier planting years and into which spruces had been notched straight through into underlying peat. Even those showed up better, although the area was not very well drained. Drainside turfs and spoil upon which trees had been planted were also seen. Just prior to the December 1926 mission, it was decided that blanks in screefed areas should be planted on the old turfs removed from the screefs several years before, and that one row, at least, should always in future be planted in the turf thrown out from the drains. The turf-nursery system devised by Sir John Stirling-Maxwell at Corrour was tried out in several forests about this time but was not continued. It is interesting to record that Dalbeattie Forest was actually the first in the district to undertake a large area of turf planting in the Belgian style; that was in 1925–6. From 1927 onwards turf planting was undertaken in a very big way at Newcastleton and the forester was quick to develop a method of planting similar to the Belgian one, although the turfs set out were considerably smaller. By 1930 he was draining and turfing practically 100 per cent. of the area at an inclusive cost of 1*s.* per chain—a remarkable achievement—and generally speaking his work was completely successful. As other new forests were acquired in south-west Scotland, turf planting became universal from about 1928 onwards on all ground of this *Molinia* type.

Newcastleton Forest itself had been almost fully planted before the ploughing technique developed, but other white land forests, e.g. Tinnisburn near by and Twiglees some 20 miles to the west of Newcastleton, became involved in some of the early stages in the development of the turfing plough. To begin with single-furrow ploughing in ridges 5 feet apart was the one method tried, heavy ploughs of the Ransome solotrac type being used. The first tractor seems to have been a wheeled John Deere and it was not until about 1937, when the advantages of a crawler type became very obvious, that Caterpillars were acquired. About this time J. C. Cuthbertson of Biggar designed his draining plough and it was first employed and gradually proved revolutionary. These tractors and ploughs did great work all through the war although naturally planting programmes gradually diminished. The end of the war brought a new phase as programmes were suddenly increased and work was started on quite a number of new forests. The result was that equipment to do the job in the old way, i.e. ploughing single furrows, was not available. In an attempt to make do with the tools available only one line in four or so was ploughed and the ridge cut up into turfs which were spaced out at 5 feet by 5 feet over the area where previously there would have been four complete furrows. This was virtually a return to the turf planting of 1927–37 and several officers thought it a retrograde step. As a matter of fact it proved to be so, especially on the poorer *Molinia* types because, in addition to the draining being 75 per cent. less frequent than with single-furrow ploughing, vegetation competition was at least doubled and almost certainly the possibilities of damage by frost to small tree plants were increased. It gradually came to be realized that a single scrap of turf certainly required a larger plant than might be essential on the long strip of turf which a draining plough turns out. Probably the main

objection to the deep single-furrow system is the fact that it provides too many and too close lines of easy fracture which might aid windthrow. This is not likely to be so important on a friable material like well-drained *Molinia* peat or any crumbly mineral soil, but on a clay or gley soil which stays put for many years and weathers down little if at all, the danger from windthrow may be much greater. On better soils than the typical white or *Molinia* land, lighter ploughs came to be used in the post-war period. These could work faster and so required less costly tractors, but the lighter ploughs never came into much favour for the really wet and difficult peat types. Anxiety over the possibilities of windthrow, coupled with disappointment over the results of turfing from furrows spaced 20 feet apart, led in turn to the development of a plough which would make one furrow supply two strips of turf. The Cuthbertson double-mouldboard ploughs began to be tested about 5 years ago and are now (1952) fairly well established on the smoother slopes on both sides of the Border. As the drain that these cut is not nearly so efficient, as such, as that produced by the proper draining tool, it is common practice now to use both ploughs on the same area, the proportion of each depending on the wetness of the soil. At the moment we have reached a state of technique on the white land, therefore, which secures adequate drainage and a very considerable turnover of turf which in itself provides a large area of easy rooting while limiting competition of grass and other vegetation. Any reference to tree species or to manuring has been avoided in the paragraphs above in the interests of simplicity. The average *Molinia* types take spruces readily and only on the poorer sites where heather (ling) or bog bell heather or *Scirpus* are frequent, and likely to increase after draining, would an admixture of pine or a dressing of phosphate be a sensible addition.

To turn now to the second major category. The black lands lie mainly on or are derived from more acid rocks than those which underlie the white lands. They are characterized by an actual or incipient mat of not very luxuriant heather or rather ling. This grows on a 2- to 8-inch layer of tough peat over the compacted glacial deposit, the top inch or so of which is often markedly leached. The Bennan, acquired in 1921 and now part of Cairn Edward Forest, was the first State acquisition in the district to contain large tracts of typical black lands; other forests with considerable areas of this poor heather land in the south-west of Scotland being Dalbeattie and Kirroughtree. Much of the land to be dealt with in the first years at Bennan was easy to plant, but patches of black land did occur and were, like the remainder, notch planted in a screef and mainly with spruces. The plants lingered on, but many eventually died on the heather patches. Direct notching of spruce into heather lands was still being done in 1924 and 1925, but it is significant that when some of the black ground, planted originally in 1922, was burned in 1926 it was then considered unfit for planting. By that time, apparently, it was recognized as a very difficult subject.

The bulk of the good land at Bennan had been planted by 1925 and what remained, in addition to typical black land, consisted largely of *Calluna-Molinia*-clad peat of a kind midway between typical black and typical white land conditions. It had been found much more difficult to raise spruces on this intermediate type

than on pure *Molinia* land. Both Dalbeattie and Kirroughtree also had considerable proportions of this quite difficult intermediate type which, in the light of present knowledge, we know has to be treated more like black than like white land if it is to be successfully afforested. At Kirroughtree especially it is now evident that many of these areas tend to develop a dense and strong growth of ling after being drained and planted with spruces, although originally it did not appear that there was much ling present. Spruce soon enters into a state of check under these conditions and seldom reaches proportions to suppress the heather. By 1927 much more draining was being done than in the earliest years, the number of chains per acre having risen from a mere 5 or 6 to something like 20. These figures probably pertain more to the intermediate than to the black ground types, on which, however, a certain amount of draining was now being done. When it was found that considerable areas of spruce on black land at Dalbeattie had gone into a severe state of check it became the practice to cut out the turf on which the tree was growing and lift turf and tree together up on to the surface of the peat. This went on on a considerable scale from 1925 to 1929.

Despite the increased amount of draining being opened by 1927, it is strange to relate that for the large-scale turfing carried out at the Bennan in that year, turfs were not taken from the drains but were actually dug out of individual holes, and overturned, vegetation downwards, alongside for the trees to be notched into. In the following year, 1928, for the first time proper turf planting *ex* drains was carried out, but it was restricted to small wet areas of peaty ground and does not seem to have extended much, if at all, on to typical black land. At Dalbeattie, on the other hand, as has already been mentioned, proper Belgian turf planting was done on land of the *Molinia* (and probably also of intermediate) type on quite a large scale in 1926, a year before turfing really got going on the big expanses of white land at Newcastleton. The year 1927 marked a further step forward in dealing with difficult ground as phosphate was employed for the first time in the district. The slow development of Sitka spruce on the black land had obviously been causing dismay. In the same year we find still another improvement recorded —an admixture of pine was employed amongst the spruces on black land types at Bennan. Phosphate has been used on most heather land at the Bennan ever since that time, but unfortunately pine has not regularly been mixed in with the spruces there. From 1929 to 1932 only small pieces of reasonably good ground were tackled at the Bennan, it having been wisely decided to lay off difficult types on the only area then available—Bennan Moss—until more was known about the proper way to deal with them. Planting began again in 1933 and much of the moss had been dealt with by 1938, although the toughest black land types were kept until the last.

In 1931 the Research Branch were instructed to undertake a series of trials on the so-called tough peat knolls which were proving so difficult in this area and in a number of other forests in west and north Scotland. The experiments at Bennan and elsewhere began in the following year and covered a range of planting methods from simple notching to special forms of pitting, turfing of various sorts, and even included a complete turning over of the surface peat by a method which

later became known as complete mock ploughing. Each method was tried with and without phosphate. In the experiments the species included Scots pine, Contorta pine, Sitka spruce, Japanese larch, and Douglas fir. Summarizing the results to date, very briefly, it may be said that phosphate has been shown to be essential if a good start is to be made and that Sitka spruce at least is useless without it. Direct notching methods are pretty hopeless even with phosphate. Turfing and certain special pitting methods give far better results, but on the whole the best growth has been made on the completely cultivated plots where, of course, the cost was greatest. Obviously the answer was plough if possible. These results apply not only to the Bennan but to the other forests where the trials were made.

By 1938 it had become apparent in these forests in south-west Scotland that even the knolls and drier slopes on the black land needed a certain amount of draining. Invariably the turfs were now used for planting upon. By this time also it had been realized that good alinement of the drains was just as important as the provision of turfs and carefully placed 'contour' drains were favoured, the number of chains running between 30 and 35 per acre on the average. Ploughing of the white lands had developed fast from 1937 onwards, but it was not until after the war that it was employed to any extent on black land types. By 1948, however, a plough of one kind or another was always used where there was any extent of ploughable black land, but seldom were there large tracts of black land which could be easily ploughed as the terrain is almost always rocky or boulder-strewn. On the other hand, we find it recorded in 1949 that at Kirroughtree Forest much ground had been unplantable until heavy ploughs appeared. On certain black land types a plough with a deep subsoiling tine has been used and has done good work, but it may be that the draining plough may prove to be more generally useful as, on particularly stony ground, a track may often be found in which to draw an irregular furrow from which turfs can be cut to space out over the area, although anything like complete ploughing would be out of the question.

As far as the white lands are concerned, there never was any good reason to depart from the practice of planting spruces. Norway or Sitka spruce are the obvious choice, the American species being kept to the less frosty ground. Later on, possibly when the peat has disappeared, as it does in time, an attempt may be made to introduce some long-living windfirm species such as oak (*Quercus* spp.).

It is quite another story on the black lands. In the beginning, in these forests, spruces were planted over practically all types including black lands. Where ling is dominant, spruces refuse to grow pure or unnursed, but it was several years before it was realized that pines started better on such sites. The planting method had been direct notching, and notching was still employed when it became the practice to change over to pines on the black lands. At first only Scots pine was used, but by 1930 *Pinus contorta* was beginning to be employed. Several years later the relatively poor development of the notched Scots pine led to the planting of pine species also on turfs, spruce having been so planted for some years.

Scots pine has been disappointing on the Silurian area which covers so much of the south-west and has never done well at the Bennan even when turf planted, and indeed on all but the very steepest areas in south-west Scotland its growth

has been thoroughly disappointing. Not only does it tend to lose its needles very readily but it does not seem to root well and one frequently finds young Scots pine swinging about, even on heather knolls.

Pinus contorta was available in such small quantities that it was almost invariably planted in little isolated groups with the result that the deer were attracted to it and did very considerable damage by rubbing their horns on the clean, smooth stems, for in these years the straight lodgepole type of Contorta was more plentiful than the strongly branched coastal species. It is now very evident from the Contorta race plots at Kirroughtree Forest that the deer leave the coastal type very much alone. Recently the coastal pine has been increasingly used as a pioneer species on the poorer types of ground. Not only is it an admirable shelter tree and nurse but good strains quickly produce reasonably straight poles. Scots pine may be worth growing with Contorta; so may other species. Mountain pine has been used high on the Bennan on heather types where it makes good growth, but, unlike Contorta, it will never produce saleable material. As has been indicated, the spruces did very badly when directly notched on to black land types and unfortunately the introduction of turf planting was not the whole solution as it had been on the white. Certainly spruces did better to begin with, where turfed, but once the ling really became dense, as it was encouraged to become by the reasonably good draining, the spruces went into check and made very poor growth indeed for many years. Even where pines were introduced 23 years ago in an attempt to bring the spruce out of check we now find the pine making good growth and actually having to be thinned although the spruce is still more or less in check. Although little evidence is actually to be had in these forests, it is fairly certain that spruce could be grown reasonably well on the black land types if good single-furrow ploughing and a heavy admixture of pines were used in new planting. Phosphate, of course, would be essential, but after years of effort it is still very doubtful if it is worth a great deal of trouble to nurse spruce up in mixture with pines.

A most important species for the black lands is Japanese larch, which was not tried nearly enough in the early years. It is now evident that if this is employed on frost-free slopes and given adequate turfing or, better still, ploughing and a phosphate dressing, high-quality plantations can be raised. Until quite recently it was the rule to plant Japanese larch only on the very best of the heather lands, usually where some bracken appeared, but it is now known that the species will do very well indeed on ploughed heather land or even heather/*Scirpus* land, i.e. on the poorest of the black ground provided the mineral soil is within reach. Hybrid larch (*Larix eurolepis* Henry) also would be well worth trying.

Douglas fir has made unexpectedly good growth in the experiments on the tough peat knolls at Bennan[1] in mixture with Scots and Contorta pine and Japanese larch and is worth an extended trial. Other exotics from western America such as *Abies grandis* and *A. nobilis* Lindley and *Tsuga heterophylla* Sarg. should also be tried. The introduction of Sessile oak (*Quercus petraea* Liebl.) for more permanent shelter strips will have to be considered later on.

[1] And elsewhere. J. A. B. M.

There is much in common between the lessons learned on both types of difficult ground. *Good drainage is essential*, and this involves both the cutting off of seepage from the slopes above and the provision of sufficient well-placed drains in the area itself. This ensures that no ground to be planted will be sodden and therefore sour for any length of time. Where terrain allows, the necessary drains are best and most economically opened by a draining plough drawn by a Crawler tractor. *The more inverted turf there is the better*, and there are two major reasons for this. First, the maximum area of extremely favourable rooting medium provided stimulates the earliest possible development of an extensive rooting system. Second, the more ground there is covered by inverted turfs the less original vegetation is left to enjoy the benefits of the draining and of the local shelter provided by the turfs which, together, only encourage the vegetation to compete more strongly with the tree plants. This is specially important on black land where heather (or more properly ling) would develop strongly and, as is now so well established, would reduce the rate of growth of all trees, especially the spruces. Besides this direct advantage obtained by turfing there are places where the elimination of grassy vegetation reduces the liability to frost damage on small plants. *Phosphate must be given if there is a deficiency*. This applies only to the black and intermediate types and not to the typical white land. It is most necessary for spruces and for larches.

ACKNOWLEDGEMENT

This paper is published with the permission of H.M. Forestry Commissioners.

SUSTENTION AND MAXIMUM BENEFIT AS ELEMENTS IN FOREST POLICY

By M. L. ANDERSON

SUMMARY

A short paper read before the British Association in Belfast in 1952 in which the main aims of sound management of a forest estate in being, and the special features of these aims from an industrial viewpoint, are unfolded for the understanding of the layman.

FROM the title it will be seen that the subject of my talk is frankly political and rather remotely related to the biological aspects of forestry, which, to judge by the affinities of this sub-section, tend to be regarded as of primary importance.

I make no apology for this because I think the political implications of the inherent nature of the existence of forests as communities of trees and other organisms are apt to be forgotten. In the various political fractions which now exist in these islands, politicians and the general public are too prone to measure the progress of forestry by the number of acres or of trees planted. That may be excusable because it is a very simple sort of yardstick, but we foresters are going to have great difficulty in educating the public and the politicians to realize what forestry, as distinct from afforestation, really means, so that they can appreciate how far we are progressing towards our ultimate objective.

The main aim of sound forest management is, of course, to bring the forest to the highest possible level of production and to ensure that such production is maintained. Today I propose to consider these questions of maximum production or benefit and of sustained production which hold a uniquely important position in forestry.

With regard to the first word used in the title of my talk, I am perhaps introducing to you something new. The word will, however, be found in the *Oxford English Dictionary*, but it has been used extremely rarely. It might well be adopted specially for forestry, however, because it very conveniently stands for something which has otherwise to be expressed by rather clumsy phrases. The word 'sustention' is derived from 'sustain', just as 'retention' and 'detention' are derived from 'retain' and 'detain'. It means 'the action of sustaining or keeping up a condition, etc.,—the maintenance of something liable to vary in size or amount at a constant level'. The thing in question is thus sustained or maintained at some level, so that we can speak of a yield being sustained, for example, and in forestry textbooks repeated references will be found to the principle of the sustained yield. Sustention as a principle, however, can be applied in forestry to more things than the yield and the principle can be better explained and understood if it is considered more generally.

Forestry, of course, is not alone as an industry in applying the principle of sustention. All industries are interested in sustention of production, of the supply

of raw material, of the means of production, of employment, of sales, of income, and of profits. Any crisis which results in any fall-off of these things is deprecated.

In forestry, from the industrial viewpoint, however, there are certain unique features which make the principle of sustention vitally important. I shall mention three.

Firstly, the means of production, known as the growing-stock of the forest, is similar in composition and in attributes to the manufactured produce, that is to the yield of timber; this makes it difficult to distinguish between them in the factory, i.e. in the forest, and to ensure that they are so related that both the growing-stock or means of production and the production itself are sustained, and also to ensure that the yield is so related to the production that both of them are sustained. I should, perhaps, clarify the distinction between the terms 'production' and 'yield'; the former refers to what the forest produces by growth, the latter to what is removed from it by man for his use. A sustained yield which is too high will cause a loss of sustention in respect of growing-stock and almost certainly of sustention in respect of production; or again, a sustention in respect of yield which is too low may result in a loss of sustention in respect of production, caused by an accumulated excess of growing-stock.

Secondly, the means of production under normal conditions is continuously renewing itself automatically, continuously producing, and normally, the production will be sustained even when, from the industrial viewpoint, there is no yield or a yield sustention of nil. Such production is, of course, wasted so far as its utility to man is concerned, unless the forest is maintained and valued for protection or some secondary function, other than production.

Thirdly, if the means of production are destroyed it takes a very long time to re-create them—normally several generations of men. At the commencement of regeneration or re-creation of the growing-stock, production is nil and remains low for a more or less long time, but gradually rises to a maximum to a point where it again becomes possible to levy a yield, which in turn can gradually be increased until it reaches a point where it approximately equals the production. When that happens it then becomes desirable that there should be sustention of both production and yield. Absolute sustention of growing-stock is impossible in the managed forest, because the removal in the form of yield of what it has produced must temporarily reduce the growing-stock, and its capacity to renew itself should sooner or later make the loss good again. Ideally the loss should be made good within the shortest possible time, that is, within a single growing season and it is a fundamental principle of forest management that that should be achieved. In forest management various methods of procedure have been devised which are designed to realize this object, some being more effective than others.

Forestry in comparison with other land-uses is greatly complicated by the fact of the time-factor, so that for this reason alone forestry is not 'merely a branch of agriculture'. Given an area of fully stocked virgin forest, in which there is virtual sustention of both growing-stock and production, a sustained yield can be achieved in several ways. A method of *integral* intermittent management may be adopted and the whole of the growing-stock felled to furnish the yield. Its regeneration up

to the stage when growing-stock and production reach optimum sizes may take, say, 100 years. At 100 years, therefore, it can be completely felled again and, if nothing has occurred during that century to reduce the productivity of the site, the yield should be the same as before. The repetition of this process will thus result in a sustained yield occurring every 100 years.

Such a yield by itself, unrelated to yields from other areas in the intervening years, obviously cannot be satisfactory to the users of the produce. The area might, however, be divided into two equal parts and one part might be cut 50 years after the other. With satisfactory regeneration on both parts we shall duly arrive at a sustained yield of half the amount every 50 years. This process of subdivision might be carried—always assuming a perfectly uniformly productive area of forest—so far, that every year 1 per cent. of the forest area is cut and regenerated which will then result in a sustained annual yield. Apart from the drop every year due to the felling and the following rise due to growth or increment, the growing-stock and the production will also be sustained in theory.

In practice, however, owing to wide variation in rates of growth, often over quite small areas, such a simple arrangement of a forest is seldom possible and may not even be desirable. Nevertheless, if a forest-owner or a country as a whole wishes to draw a more or less constant revenue annually from the forest in perpetuity, and it may be taken that the revenue is a measure of the usefulness of the produce, steps must be taken to bring about a satisfactory balance in the age-classes of the trees constituting the forest. For the private forest or for the country's forests as a whole there is an optimum growing-stock giving an optimum volume production and if sustention can be achieved in respect of these, a sustention of yield should follow. Sustention of revenue is less easily realized as the value of the yield is outside the control of the forester to a great extent.

These sustentions are, of course, ideal objectives of a forest policy. They may be realized in exceptional circumstances, but they are constantly threatened, not only by disturbances due to natural agencies, such as disease, storms, or insect attacks, but also by effects of economic pressure, which may in times of crises be unavoidable, or even by silvicultural action designed to bring about long-term improvements at the expense of temporary sacrifices. Then again, how can one be sure, even after these sustentions of growing-stock, production, and yield have been realized, that they are the ones best suited to the needs of the owner or of the community, and that they are such as to enable the forests to fulfil all their functions of protection, production, &c., to the highest degree possible? This leads to a consideration of the principle of maximum benefit as applied to forestry and as an element in forest policy.

It is not in man's nature to be satisfied with benefits which remain the same. He wants to reap increasing benefits from the forest and these can often be increased by improving the management. In determining maximum benefit it is necessary to take into consideration, not only the productive role of the forest, but its protective role and even its secondary functions, although the measurement of the relative value of these latter is almost impossible in terms of money. It must often be accepted, however, that the production from forest areas

required for protective or secondary purposes must be less than the maximum which might be attained but for these requirements. This will often be so in respect of the *value* of the produce as distinct from its *volume*.

Moreover, maximum benefit from the purely productive functioning of the forest is concerned, not merely with the amount of that produce, but also with its form and value. Not only do we want to achieve a sustained yield from the productive forests, but a sustained maximum yield, and, not merely a sustention of the highest possible quantity of produce, but also of the highest possible quality, quality meaning usefulness as indicated by the price which the produce fetches.

The nature of the produce will often be determined by the locality conditions as well as by the local requirements of the population. In certain areas the production of firewood may provide the highest benefit, in others the production of pitwood, and so on. In others again the locality conditions and the existing forest may be such that they furnish the highest benefit by producing high-class timber, which may not be in demand locally. It might be sound policy, in that event, to grow oak veneer timber while, in fact, the greatest local demand may be for coniferous timber.

Sustained *production* is a goal to be sought after in every forest of whatever kind, even in one managed for aesthetic reasons only, otherwise the forest must inevitably disappear, a point the laymen usually overlook.

Sustained *yield* is also a goal to seek in all productive forests and in all protective forests and forests with some secondary function to perform, when these can be exploited without harm to their functions. Being more easy to realize than the maximum yield or maximum benefit, as an objective it will normally precede these. It is easier of achievement as it is much less dependent upon factors external to the forest.

To achieve the maximum yield or maximum benefit should be a normal sequel to achieving sustention of yield. The main difference between these two objectives is that maximum benefit is never constant, but changes along with complex social and economic factors and even with changes in silvicultural technique which may increase both the quantity and the quality of the produce.

This has led us to the modern idea of 'progressive benefit', which in a sense combines the ideas of sustained yield and maximum benefit. The idea of sustention of yield at some fixed amount for any forest or group of forests leaves out of account the possibility of any evolution of economy or of progress in silvicultural technique and is contrary to modern ideas of forest management. Such a possibility of progressively increasing benefit and of a dynamic as opposed to a static form of management should be accepted. As each step towards maximum benefit, which is a theoretical objective never achievable, is reached, its sustention will then become an objective of management involving changes of procedure, which will in turn be adhered to until such time as a further step is taken towards the ideal goal.

The essential justification for the principle of the sustained yield is the need to guarantee sustention of supply and the greatest possible stability to the timber-using industries, to industries using produce derived from the forest, and to all those people dependent upon these industries.

Like all industry in general, these industries are liable to suffer disturbance and dislocation due to general crises hitting a number of countries or even the whole world. The aim of a sound general economic and social policy is to avoid these crises. Forest policy, as an element in that general policy—and often a major one in countries rich in forests—can, and should, lessen the risks or ill-effects of these crises by guaranteeing sustention of production and of yield. Where a large number of workers are engaged in forest industries there is a social justification apart from the indirect economic one.

When the importance of sustention of yield from a country's forests has become generally appreciated and accepted, and it is one of the forester's main tasks to see that it is, that, in turn, will ensure the stability of the forests themselves, since it is clear that the yield cannot be sustained if the growing-stock and production are not sustained, unless improved technique can increase production. The need for adequate creation and conservation of forests will then be better appreciated. Acceptance of the principle of sustention as an element in forest policy implies that over the whole of the national forests the volume of each category of timber, having regard to its various uses, exploited each year shall correspond exactly to the increment of that category. In this strict application of the principle both the permanence of the forests and their ideal composition are prerequisites.

The principle of progressive benefit needs no justification as it is only logical to endeavour in these increasingly hard times to extract from the forest as a whole the maximum benefits which they can yield in the general interest, and it is only wise to accept that these benefits are not static but may vary and be increased. For example, under certain conditions forests may provide the maximum benefit in an aesthetic capacity, but changes in population needs may demand that they should function productively. Then again, demands for a new class of timber, say for a high-class veneering timber, may require that the production of a less valuable category should be gradually dropped to enable the more valuable veneer timber to be produced, and so on.

It may be relatively easy for a country to decide that the principles of sustained yield and of progressive benefit should form elements in its forest policy; it will be more difficult, however, to take the steps, even long-term steps, to implement that decision. Obstacles to this may be, on the one hand, of a physical nature, and, on the other, of a political or economic nature.

The main obstacle usually is the lack of sufficiently detailed information about the growing-stock and production of timber and other materials in the whole of the forests of a country, or even over any substantial part of them. Recently considerable progress has been made with national forest surveys which provide the basic information required but they are rather costly. Censuses have been made in these islands providing data upon which control of fellings is being based and discussed. It should be an element in forest policy to initiate or repeat these surveys.

Then again, to apply the principle of sustention satisfactorily in practice implies that for each type of forest the stand must be so constituted that it is best suited to that type. The best compromise to ensure satisfactory perpetuation of the stand and to maintain the fertility of the site and at the same time to obtain

the desired sustention of yield or of other benefit will vary with the forest-type and it cannot be discovered without very long-term study.

To achieve sustention of the maximum benefit, even in its simplest form of the highest volume production of a given assortment, say oak constructional timber, raises many problems of silviculture, which can be solved only by very long-term research work. Where study or experience has shown that in the long run more ultimate benefit will be secured by changing or converting the composition or constitution of a forest than it provides in its existing form, the achievement of the maximum benefit becomes much more complicated.

These technical difficulties require constant research, which it should be one of the elements of a forest policy to provide.

When any country adopts as an essential feature of its forest policy the principles of sustained yield and maximum benefit, in practice it means the enforcement of conservation or rehabilitation and of the economic development of the forests of that country. That will present no difficulty when the whole of the forests and related industries are State-owned or State-controlled. In many countries, however, most or all of the forests may be privately owned. In some countries these private forest-owners are highly organized on a large scale and may have evolved and be operating a policy of their own. If so, and if experience has shown it to be in the best interests of the whole community, the general policy adopted by the Government might well be made to conform to that of the owners.

Otherwise the Government may have to draw up a completely new national policy and endeavour to get forest-owners, and especially those whose forests are not being worked to give either a sustained yield, or the maximum benefit, to conform to that policy. This may be said to be the position which has arisen in these islands. The legal nature of an owner's tenure of his forest property or even the fiscal demands made by the State upon his property may be serious hindrances to his application of the principles of sustained yield or maximum benefit. The collection of estate and death duties is a case in point.

The general political outlook of the country may prevent any interference with the individual's rights of user in his forests, in which case the policy will have to be one of education and persuasion and the enactment of some form of legislation which will encourage owners to adopt procedures which may be contrary to their own immediate interests or those of their successors in ownership but in the general long-term interests of the community. This may mean a system of taxation relief or of payment of subsidies or some other form of financial aid, or it may involve the use of tariffs upon imports or the assistance of timber exports.

Lastly, a major obstacle in applying the principles under discussion is, of course, ignorance of their existence and of what they mean. I hope what I have said may help to remove that obstacle and lead to a greater appreciation by politicians and other laymen of the special economic position which forestry as an industry holds.

ACKNOWLEDGEMENT

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THE REHABILITATION OF DEVASTATED WOODLANDS

By J. E. GARFITT

SUMMARY

The paper discusses in detail the methods being employed to restore productivity quickly and economically to 1,200 acres of privately owned woodlands, mostly hardwoods, from which all timber 12 inches quarter girth and over had been removed during the war.

THE recent census (3) carried out by the Forestry Commission shows that over 40 per cent. of the privately owned woodland in Great Britain is either cleared, derelict, or devastated. It is in the devastated woodland that the forester finds his biggest problem, i.e. how to convert acres of smashed and damaged material into productive woodland at least cost and with least loss of time (1, 2). For cost and time are both of vital importance to the private owner of woodland. There will be no need to elaborate the cost theme. As to loss of time, no owner in these days will be prepared to wait longer than he need for his woods to become productive once more, even if the Forestry Commission did not have power to remind him of his duty in this respect. The following is an account of the methods adopted at Cirencester Park, the Cotswold seat of Earl Bathurst, to whom the writer is indebted for permission to publish this paper.

The woods concerned are Oakley and Overley Woods, totalling approximately 1,200 acres. These woods were visited by members in 1951. Prior to the Second World War, they consisted of standards of beech (*Fagus sylvatica* L.), oak (*Quercus* spp.), ash (*Fraxinus excelsior* L.), sycamore (*Acer pseudoplatanus* L.), and larch (*Larix decidua* Mill.) over hazel (*Corylus avellana*) and, locally, wych-elm (*Ulmus montana*) coppice, the rotational cutting of which had ceased many years previously. During the war all trees over 12 inches quarter girth at breast height were felled with the exception of avenue trees and a few individual trees specially marked for retention. Little regard was paid to the undersized trees, which were left standing, so that many were damaged during felling and extraction. As the underwood was not cut before felling began, a great deal of it was smashed and broken, being left in some places in a tangled mass. In one respect, the woods were more fortunate than some in containing no old tops, overgrown with bramble (*Rubus*) and bracken (*Pteris*). A clear agreement before felling started ensured that this burden was not added. Casual inspection showed little of value remaining in the woods, but detailed investigation revealed a considerable quantity of young ash with clean butts though with somewhat restricted crowns. There were groups of sycamore poles worth helping, though many had been damaged in the crown by grey squirrels. A proportion of the oak remaining looked capable of putting on useful increment. In addition, there were groups of established regeneration of sycamore and ash, with a little birch (*Betula* spp.). To set against this, rabbits abounded; the grey squirrel population was very large in peak years; and fallow deer roamed in the woods.

In deciding on treatment, the following had to be borne in mind.

i. A productive crop of some sort had to be established cheaply over the whole area in the shortest possible time; once this had been done, it would be comparatively simple to improve it later.
ii. The general broad-leaved character of the woods had to be preserved while introducing a rather higher proportion of the conifers—European larch and Scots pine (*Pinus sylvestris* L.) for which the woods were noted in the past.
iii. Cover for game had to be preserved and the overall appearance of the woodlands maintained during the conversion period.

Furthermore, experience gained in the adjacent Hailey Wood which had been clear-felled showed how inadvisable it was to undertake widespread clearing. In this wood, forest conditions had been lost even up to 8 years after felling, and with the surface soil dried out by wind and sun, the re-establishment of tree growth remained severely checked.

These considerations, coupled with the fact that the fellings had not been sufficiently heavy to cause any major disturbance of the forest climate or soil, led the late Ray Bourne, who was called in to advise, to stress the importance of enlisting the aid of all possible natural seedling growth and coppice and of reducing clearing for planting to a minimum. As much of the advance growth was in groups, the group was adopted as the basis. In addition to groups of advance growth, any trees retained were if possible to be kept in groups. Plantings, too, were to be in pure groups, approximating in size to the natural ones and set between them. Thus a form of group selection was to be established right from the start and the need for future clear-fellings avoided. Rabbits had to be drastically reduced and three keepers were given the prime task of destroying them over the 2,000-acre block of woodland.

In practice, three techniques or treatments have been developed.

I. *Where stocking with trees, poles, and seedlings is complete*

A great deal of heavy work is required to bring such areas into a productive state, as the material present is in an extremely raw condition. Typically, they consist of widely spaced, rather small oak, sycamore, and ash, many of bad shape, with poor crowns and probably damaged during felling operations. Below and around them are patches of advance-growth of sycamore, ash, and birch; some small and badly nibbled by rabbits, some large, whippy and bent, with a tangle of brambles to a height of 5 feet around their stems. Other ash seedlings are found emerging from dense patches of bramble. And scattered throughout, obstructing the growth of seedlings everywhere, is broken old hazel-coppice. In their untreated state such areas are virtually impassable in summer except along old dragging-tracks. The prescriptions are as follows:

a. Cut all hazel and other underwood.
b. Thin out groups of advance-growth to about 2½ feet spacing, retaining the best stems, and cutting the others cleanly back to the ground. The latter

will shoot again and may be of some use later. Keep spacing close as stems of this kind, grown in dense clumps, are often very thin and whippy, and unable to stand alone if opened too far at first.

c. Reduce to one shoot per stool any useful ash or sycamore coppice-poles. Poles to be retained should be of good shape and 'break' from a point low down on the stool in order that, as they grow in girth, poles may put out new roots of their own and not be forced to depend on the old roots of the partially decayed stool.

d. Fell all trees in the overwood which either have no prospect of putting on further increment or are not required as seed-bearers or to provide shelter. Where the overwood is thick, there will be a wide choice and shelter will be provided by vigorous trees of good shape. Where the overwood is thin, some rather inferior trees may have to be kept for a while.

The felling is of some delicacy and not normally to be entrusted to a timber merchant. The direction of fall of each tree has to be decided with reference to the surrounding mass of natural regeneration and to the line of extraction that it can most conveniently share with others. Cording of tops and burning of brush is done before the timber is removed. This is done preferably with a rear-winch tractor, the butts being hauled by winch in a straight line to the nearest arterial dragging-track and then drawn out to a convenient ride for loading. When timber extraction is completed, the same routes are used for the extraction of the cord-wood. In this way, comparatively little damage is done. When crowns unavoidably destroy advance-growth, it is cut back to shoot again clean. The dragging tracks themselves, which are often worn deep with the surface soil torn off and the clay puddled and compacted, may remain uncolonized by new seedlings for many years. As, however, extraction routes are always required under this system, firstly for bean-sticks from early thinnings and later for larger material, this need be no disadvantage, provided the original layout is correct.

II. *Where stocking with trees, poles, and seedlings is incomplete. Full treatment*

Such areas are similar in many ways to those described above, but contain considerable blanks where no utilizable tree-growth is to be found. Typically their openness has led to a strong coppice-growth, with heavy bracken or bramble. The few larger trees in these open patches generally occur singly, rarely in groups. As between 7 and 10 years have elapsed since the war-time felling, it is reasonable to assume that such areas are unlikely to become colonized in the near future. It is these blank areas which are planted.

Treatment begins with the clearing of weed in the blank areas, and for this the Allen Autoscythe has been used with considerable success. Where sporadic ash or sycamore regeneration occurs among this weed, e.g. 2 foot ash under heavy bracken, its presence is ignored and the whole mown off together, the young trees being cut as low to the ground as possible. Following the cutting and burning-up of the weed, operations continue along the lines indicated for Treatment I above. After extraction of all timber and firewood has been completed the whole area, or that part of it containing substantial blanks, is wired in with a rabbit-fence.

Planting then proceeds in the blanks between the groups of regeneration. Details of the technique have varied, but generally the plants are massed in pure groups about 20 yards in diameter, this being comparable with the normal size of a natural group of ash or sycamore. In cases where the blanks are of considerable size, the planted groups are arranged in checkerboard fashion. As indicated previously, European larch and Scots pine have been used a great deal in this work, but more variety is to be introduced by using substitutes for the latter. Shade-bearers are of special value in work of this kind and *Tsuga heterophylla* and *Sequoia sempervirens* may play an important part in later developments. At the corners of these large groups, small groups of beech are inserted, employing 9 plants as against the 144 of the conifer groups with the intention of producing one tree from each group without a superabundance of valueless thinnings. Only beech from the estate's own 'Pope's Seat' strain is used. Planting is at an orthodox spacing of 5 feet, except where sporadic regeneration exists. Since one natural seedling between two plants will reduce the effective spacing by half, in such locations the spacing is increased to 10 feet. Plants are set out in straight lines in the ordinary way for convenience in planting and early weedings, the groups of advance-growth being 'leap-frogged' and the lines continued beyond. No beating-up is considered necessary in these areas owing to the constant supply of new seed from the seed-bearers.

III. *Where stocking with trees, poles, and seedlings is incomplete. Partial treatment in advance*

This consists simply in the cutting of the old hazel in compartments not scheduled for very early treatment but in which acceptable natural regeneration has appeared. These big hazel-stools throw a great deal of shade, thus preserving a clean floor below. This is often found to be sown densely with ash or sycamore seedlings, 1 or 2 years old. If left unassisted, the majority of these will die from lack of light or at best will straggle out towards the light as bent and partially suppressed stems of no value. If freed by the cutting of the hazel, they are able to grow rapidly into straight-stemmed groups of advance-growth, ideal material among which to carry out the method of conversion first described. Many hazel-stools do, indeed, shoot again although a high proportion are too old and weak to recover; but the space occupied by their young shoots is only a fraction of the original area covered. No other steps are taken beyond the cutting of the coppice and burning of the brush. The whole object of the operation is to give the area a chance to improve its condition before it becomes due for intensive treatment.

It will be observed that only Treatment II above provides for the introduction of conifers or other species not already present. This results from the subordination of this aspect of rehabilitation to the necessity for getting the whole area of woodland under productive crops in the shortest possible time. It is expected that oak and beech will spread gradually into areas of ash, where the light available will be sufficient for young seedlings. They will have priority when cleanings and early thinnings take place in the regeneration groups, resulting in an increase in their numbers over the years. It may also be considered desirable in due course

to plant beech or conifers in gaps resulting from fellings of mature trees or groups of trees from time to time, or even to create gaps artificially for this purpose.

Unfortunately it is not possible to make a direct comparison between these methods and the more orthodox clear-felling and planting in terms of costs. The obstacle is a fundamental one, namely, that although both methods will produce a fully productive woodland, they will not produce woodland of the same type. Thus clear-felling and planting will bring in a considerable cash return, as every saleable product on the area will have been cashed. The rehabilitation method under consideration produces a productive wood without cashing more than a proportion of the capital standing on the area. If then the rehabilitation work can be carried out *at a profit*, it may be considered a very satisfactory method of treatment for a private estate to undertake. Recent figures, therefore, will be of interest. Oakley Wood Compartment 39, treated during the forest year 1950 by the method described under II above, cost £760 gross to treat and produced a sum of £1,006 from material removed during the improvement operations. This represents a net profit of £246 on 28·6 acres or £8. 12*s*. per acre. An example of the method described under III above is presented by Oakley Wood Compartment 49, which was treated during 1951. The cost of cutting the hazel was £97 and the return from its sale, almost entirely from firewood, amounted to £103. Thus there was a net profit of over £5 or 4*s*. per acre on 25 acres. In this compartment, of course, the heavy work of conversion to productive woodland will not take place for some years. When it does, however, the outturn will consist almost entirely of timber and saleable ash and sycamore poles, and a fair rate of profit is expected, as there will be no planting or fencing required.

It is perhaps not out of place to mention that any woods to be rehabilitated along the lines described should be kept under Schedule B for income-tax purposes and not transferred to Schedule D as in the case of planting after clear-felling.

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DESCRIPTION OF FIGURES IN PLATE

Fig. 1. Treatment I. Overley Wood, Compt. 1. 1950. Initial treatment completed. Dense seedling sycamore in foreground, established regeneration right centre and groups of young trees retained.

Fig. 2. Treatment II. Oakley Wood, Compt. 38. 1949. Initial treatment completed. Stages of natural regeneration of sycamore, ash, and birch and young trees retained. Foreground planted European larch where dense shade from old beech since removed had prevented regeneration.

Fig. 1

Fig. 2

PLATE I

VARIATION OF DENSITY IN STEMS OF DOUGLAS FIR

By L. CHALK

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SUMMARY

In a disk from the stem of a very fast-grown Douglas fir (*Pseudotsuga taxifolia* Brit.), 19 years old, with an almost constant ring-width of about $\frac{1}{3}$ inch, the density of the individual rings was almost constant from pith to bark and there was no sign of any increase outwards such as was found by Turnbull in fast-grown South African pines. Similar results were also obtained with more closely grown material (mean ring-width about $\frac{1}{10}$ inch). There appeared to be no general relation between density and ring-width, but the highest densities occurred in rings less than 6 mm. wide in the centre of the fast-grown tree and at the outside of a tree with access to river water.

VARIATION in the density of softwood timber has received considerable attention from the very earliest studies of wood, but still remains a problem. One of the more recent and more revolutionary hypotheses is that propounded by J. M. Turnbull (9) for the fast-grown pines in South Africa produced by the unusual silvicultural technique developed by Craib (4 and 5). This hypothesis would have such important implications, if it were generally applicable, that it is surprising that it has not yet been tested on other species in other parts of the world. The chance possession of some demonstration material of Douglas fir, with extremely wide and regular growth rings offered an opportunity to make such a comparison on a small scale, as the rings were wide enough to study the density of each one. This specimen was supplemented by material that had already been examined for another purpose (2).

The wide-ringed material consisted of a disk whose history was unknown beyond that it was grown in Great Britain. It included 19 growth rings with an average width of 0·335 inch; the early rings were rather narrower and the average for the last 13 rings was 0·41 inch. The other material consisted of disks cut from logs described in a previous paper (2). These contained 20 growth rings, averaging about 0·11 inch, and were from an even-aged plantation growing near Lyndhurst Road Station in the New Forest. To obtain reliable figures for comparing density a 'specific gravity' was calculated in which the weight was determined on oven-dry material, but the volume on saturated blocks, in order to avoid the inaccuracies that occur in attempting to shrink a wood down to its minimum volume The volumes were obtained by measuring the weight of water displaced. Blocks for the 'specific gravity' determinations on single growth rings were taken along two radii, so that there was a pair of blocks for each growth ring from which a mean was obtained. The maximum difference in specific gravity between the two members of any pair was 0·023.

Turnbull wrote several papers (e.g. 7 and 8) about the density of pines and other softwoods grown in South Africa; his results and conclusions are, perhaps, most

clearly summarized in the paper he presented at the British Empire Conference in 1947 (9). Briefly, his hypothesis was as follows. The growth rings of conifers usually decrease in width from the pith outwards at any one level, while at the same time the density of the wood increases. From this it has been generally assumed that ring-width and density are causally related, but, in the pines at any rate, this apparent relation is entirely accidental and misleading. It is possible to find trees grown under Craib's system in which the rings become gradually wider instead of narrower, yet Turnbull found that density still increased outwards. From his observations he deduced that the increase in density outwards is determined solely by age from the pith and has nothing to do with ring-width.

In the fast-grown material of Douglas fir used in this investigation, the rings did not actually increase in width to the outside, but the width of ring was sufficiently constant to make sure that ring-width should not be a primary factor in any change in specific gravity observable from the pith outwards. The only rings that were significantly narrower were the first four or five near the pith. The material thus gave an excellent opportunity of observing whether the increase in density from the pith outwards observed by Turnbull occurs in Douglas fir independently of ring-width.

The individual specific gravities for each growth ring are given in column (*a*) of Table I. The highest figures in Tree I occur in the first five or six rings, after which the specific gravity settles down to about 0·37, with slight fluctuations in either direction. This is the reverse of what is postulated by Turnbull's

TABLE I. '*Specific gravity*' *in different rings at one level in the tree*

Ring No.	*Tree I*		*Tree II*	*Tree X*
	(*a*)	(*b*)	(*c*)	(*d*)
1 . .	..	..		..
2 . .	0·504		0·365	
3 . .	0·450	0·475		
4 . .	0·470		0·368	0·472
5 . .	0·551			
6 . .	0·412	0·454		
7 . .	0·398		0·332	0·365
8 . .	0·340			
9 . .	0·395	0·369		
10 . .	0·371		0·358	0·363
11 . .	0·330			
12 . .	0·395	0·364		
13 . .	0·367		0·368	0·433
14 . .	0·341			
15 . .	0·357	0·359		
16 . .	0·378		0·350	0·422
17 . .	0·356			
18 . .	0·372	0·371		
19 . .	0·384		0·388	0·490
20 . .	..	..		
Bark .				

hypothesis, which demands a steadily increasing specific gravity from the pith outwards.

Specific gravity for the smaller stem (Tree II) showed extremely little variation, except for a slight rise in the outer three rings. It was not feasible to measure individual rings in this specimen and each block was split off so as to contain three rings. The means for the three rings are given in column (*c*) of Table I, under 'Tree II'. For comparison the values of the individual rings in Tree I have also been grouped in three's and are given in this form in column (*b*).

The specific gravities of these two trees are remarkably similar, in spite of the marked differences in their growth rates—the diameter of Tree I was 31·5 cm. (12⅜ inches) compared with only 11·7 cm. (4⅝ inches) for the 1-year-older stem of Tree II. The narrow-ringed tree lacks the slightly higher values for the innermost rings, but is otherwise almost identical.

Figures are also given in Table I (column (*d*)) for a further stem (Tree X) from the same plantation as Tree II. This is a rather special stem from a tree that had gained access to river water and, apparently as a result, had a higher percentage of late wood in its last ten rings (2). In the early life of this tree, presumably until the roots were able to tap this source of water, the specific gravity was again very similar, starting with a slightly higher value at the centre and sinking to about 0·365.

It is clear that there can be no very close relation between ring-width and specific gravity in this material, in which the values for Trees I and II are so similar, though the ring-widths of Tree I are on the average more than three times those of Tree II. The highest specific gravities (above 0·42), however, all occurred in rings less than 6 mm. wide, namely in the first few rings of the fast-grown tree and in the outer rings of the tree that had access to river water. If these values are excepted, there is no evidence whatever of any relation between specific gravity and ring-width in this material.

The material examined was intended primarily to provide an indication of whether or not Turnbull's relation between specific gravity and number of rings from the pith exists in Douglas fir. For a fast-growing species such as this, any such relation would have important practical implications. No evidence, however, was found of any such relation, but neither was there evidence of any clear relation between ring-width and density, so that the practical conclusion that he drew—that a tree may be grown extremely rapidly without decreasing the density of its timber—received unexpected confirmation, though it is possible that the highest densities may occur only in relatively narrow rings.

Alexander (1) has recently published the results of a much more extensive investigation into the properties of a second-growth Douglas fir in Canada. He found that, in the material tested, the ring-width was almost constant up to the 90-year age-class and that 'density increases with increase in the radial distance from the pith'. This would appear to provide clear confirmation of Turnbull's hypothesis, but Alexander says elsewhere that in the area sampled 'growth rate is too rapid for high density' and that 'specific gravity is influenced strongly by the rate of growth and increases with increase in the number of rings per inch'.

It seems possible that some of the difficulties in this problem may be due to the inadequacy of ring-width as a measure of rate of growth and of rate of growth as an index of qualitative growth conditions. Obviously a wide ring near the centre of a tree may be produced by a lower rate of growth than a narrow ring at the outside of a large stem. Rate of growth would clearly be more accurately indicated by the area of the ring, but this has yet to be proved to be more closely related to the properties of the wood than ring-width (though it has been found more satisfactory for correlating with growth factors); in any case, ring area would be impracticable as an index of quality for the man in the field.

The permanent characteristics of the site and the temporary condition of the crop may well be of greater significance than the actual rate of growth. Among the site factors, those affecting the availability of water during the latter part of the growing season appear to be of special importance. This is borne out by the author's investigations on the relation between the amount of late wood formed and the moisture available at the time of its formation (2 and 3), and by the work of Paul and Marts (6), who found that all-the-year-round irrigation of Longleaf pine was accompanied by a significant increase in the proportion of late wood. The influence of spacing on late-wood formation may, perhaps, be exerted through root competition and the temporary increase in density often observed after a thinning might well be due to a reduction in the number of trees competing for a limited supply of water. Early wood formation is less likely to be limited by water supply and appears to be more dependent on factors, such as temperature, that affect the activity of the crown (3). This might make it possible to explain the absence of the maximum wood densities from trees of extremely rapid growth, even if there were otherwise no general relation between ring-width and density.

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THE CHECKING OF FOREST TREES BY HEATHER

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SUMMARY

Experiments on podzolized heather moor at Allerston Forest have shown that a heather mulch applied around checked Sitka spruce (*Picea sitchensis* Carr.), Norway spruce (*P. abies* Karst.), and Lawson cypress (*Chamaecyparis lawsoniana* Parl.), or more simply the elimination of living heather by surface hoeing, produces improved colour and vigour of the trees. It has also been demonstrated that the addition of a nitrogenous fertilizer to checked Sitka spruce can, at least temporarily, alleviate the condition of check.

ONE of the features associated with spruce and certain other conifers in the afforestation of low-quality heather moor is the liability to check. Whilst improved methods of planting have contributed towards better growth of tree crops, check still occurs and the need for a clearer understanding of the factors involved has been apparent for a long time. The object of this paper is therefore to place on record various observations and the results to date of several recent experiments associated with the checking of conifers as undertaken in the Wykeham and Broxa areas of the North Riding of Yorkshire.

These areas typify the more difficult sections acquired locally for afforestation. The geological formation is Lower Calcareous Grit (Jurassic), but the upper soil layers are markedly acid. pH readings of 3·0–4·0 have been recorded at the surface with a gradual change to 5·0 at about 24 inches depth. The soil, a compacted sandy loam interspersed with small rock fragments of the parent material, shows marked podzolization, and a thin hard iron pan occurs at 6 to 20 inches depth, whilst at the surface there is a 2-inch to 3-inch layer of tough amorphous peat. The existing vegetation is predominantly *Calluna*. The elevation is 700–50 feet and the sites, being parts of extensive and almost flat plateaux, are fully exposed. The annual rainfall is 25 to 30 inches.

At the end of 1938 a series of height and current growth measurements in an 11-year-old experiment on shallow ploughing revealed that Sitka spruce when in mixture with Scots pine (*Pinus sylvestris* L.) had begun to emerge from check. Evidently Scots pine could play some part in promoting improved growth of checked Sitka spruce, but no evidence was forthcoming of the reason. Nor did the mixture, in its existing form, offer a practical means of raising spruce as a final crop, since the pine nurse continued to outgrow the spruce and eventually suppressed it. A year or so later it was observed that Sitka spruce when growing adjacent to Japanese larch (*Larix leptolepis* Gord.) in canopy showed markedly improved growth and colour. Excavations revealed vigorous rooting by the spruce below the adjoining larch, but not within the area occupied by the spruce. Further, whereas the spruce were encompassed by vigorous heather, the heather had been killed below the larch, presumably by shading. This suggested an adverse

interaction between living heather and Sitka spruce in which the conifer was at the disadvantage.

To test this, a series of demonstration plots within severely checked plantations in dense heather was laid down over a period of years, using a heather mulch heavy enough to kill the underlying living heather. Details and results of these trials are given below.

Wykeham: Experiment No. 71

A heather mulch was applied in September 1941 to a block of 10-year-old Sitka spruce, comprising 200 trees spaced at 5 feet by 2 feet on medium-depth double-furrow ploughing. The spruce had received basic slag at planting. An adjacent block of spruce of similar history, development, and area was reserved as a non-mulched control. Six months after treatment there was a colour improvement in the mulched plot. In 1942 the mean annual growth was: mulched 3·2 inches, control 1·7 inches; by 1944 it was 9·0 inches and 2·6 inches respectively, and at the end of 1949 the mulched trees averaged 7 ft. 8 in. in height as against 2 ft. 10 in. for the non-mulched controls.

Wykeham: Experiment No. 79

A heather mulch was applied in June 1944 to a block of 8-year-old Norway spruce comprising 50 trees spaced at 5 feet by 4 feet on medium-depth double-furrow ploughing. Half of the trees had been treated with basic slag 2 years after planting. As in the previous experiment, a control of exactly similar history was provided. Average heights before mulching were 12 and 13 inches. Six growing-seasons later they were 4 ft. 1 in. for mulched trees and 2 ft. 1 in. for the non-mulched controls.

Wykeham: Experiment No. 58

A heather mulch was applied in November 1945 to a block of 7-year-old Lawson cypress on medium-depth double-furrow ploughing plus subsoiling. The trees were spaced at $4\frac{1}{2}$ feet each way; 80 per cent. had been slagged at planting, of which 342 were mulched and 108 were left untreated. One year after treatment average heights were 2 ft. 10 in. for mulched trees and 2 ft. 9 in. for the non-mulched. Three years later the figures were 5 ft. 3 in. and 3 ft. 0 in. respectively. The difference in general appearance between mulched and non-mulched Lawson cypress is striking, for the latter carry sparse dirty-yellow foliage whereas the mulched cypress carry abundant green foliage.

Mulching had led to considerable improvement in the condition of three coniferous species. Periodic inspections, however, revealed that whilst living heather had been eliminated, the slowly decomposing mulch had provided a humus layer in which the tree roots branched freely. The next step, therefore, was to test the effect of the simple elimination of living heather. Details of the two experiments carried out are as follows:

Broxa: Experiment No. 19

An area was completely ploughed 12 to 16 inches deep in the early spring of 1946 to accommodate four units each of $3\frac{1}{2}$ square chains. One-year-old seedlings of Sitka spruce and Scots pine were planted in mixture a few weeks later at 4 ft. 6 in. spacing. Bone-meal was applied to two units at planting. In July 1949 reinvading heather was covering the

ground almost completely, and the spruce showed the usual symptom of poor colour which precedes the onset of check. In two units selected by chance a petrol-driven rotary hoe was conducted between the tree rows, thus killing most of the heather. In the remaining two units the heather was allowed to develop. Four months later there was a colour response in the spruce to rotary hoeing, and at the end of 1951 average heights were (the use of brackets indicates results with bonemeal applied at planting): Sitka spruce rotary-hoed 40 inches (48 inches); not rotary-hoed 30 inches (40 inches); Scots pine rotary-hoed 40 inches (48 inches); not rotary-hoed 37 inches (44 inches). It remains to be seen whether the rotary-hoed units will form canopy before the effect of further reinvasion by heather makes itself felt.

This method of vegetation control is similar to the Danish practice of ploughing between tree rows to promote improved growth in checked plantations.

Broxa: Experiment No. 20

In 1946 six 48-tree units of 3-year-old Sitka spruce covering several methods of ploughing were demarcated for annual hand-hoeing as a means of heather suppression, and six similar units were marked off as untreated controls. The trees were spaced at 4 ft. 6 in. and had received basic slag at planting. At each hoeing, soil and peat disturbance was kept at the absolute minimum. The following data are taken from the units of shallow single-furrow ploughing plus subsoiling where reinvasion of heather was more rapid and dense than it was in the more intensively cultivated units. At the first hoeing in 1946 the average height of the spruce was 18 inches in the hoed treatment and 19 inches in the untreated control. Reinvasion of heather was at this stage only partially complete and the spruce were reasonably vigorous and carried a good colour. By the end of 1948 the hoed spruce were 35 inches high and the controls 28½ inches, the growth for that year being 8½ inches where hoed and 1½ inches where not hoed. Reinvasion by heather in the control plots was by this time heavy and complete. The hoed spruce had steadily improved, whereas the trees in the unhoed units had deteriorated markedly in colour and growth and were in fact checked. During 1949 and 1950 the hoed spruce were heavily attacked by the green spruce aphis (*Neomyzaphis abietina*), and growth fell off by about 25 per cent. The checked controls were not attacked by the aphids.

The Broxa experiments demonstrated that the suppression of living heather without the addition of imported material where rooting could take place resulted in much improved colour and growth of spruce.

Two independent observations suggested a basis for further investigation.

i. In a series of local experiments excellent colour and growth of Sitka spruce had been obtained by the use of the leguminous shrub broom (*Sarothamnus* [*Cytisus*] *scoparius*), irrespective of whether or not there was reinvasion by heather.

ii. A yellow to yellow-green colour of the needles is characteristically associated with trees in check.

These suggested a nitrogen deficiency, and to test this the following experiment was carried out.

Broxa: Experiment No. 78

An area of Sitka spruce and Scots pine in mixture, planted in 1945 with basic slag on deep ploughing, was selected as eminently suitable material. Heather had reinvaded after

ploughing and the spruce showed every sign of going into early check. Spacing was 4 ft. 6 in. and the method of mixing was 3 rows of spruce alternating with 2 rows of pine. The double rows of pine thus formed excellent buffers between the units of spruce. Two manurial treatments were applied to the spruce in June 1950:

Nitrogen: 2 oz. of nitrogenous fertilizer per tree.

Phosphate: 2 oz. of ground mineral phosphate per tree.

In addition the two treatments were combined and controls with no manurial treatment were included. The unit of experiment was a plot of 27 trees, i.e. 9 trees in each of 3 adjacent rows, and it was replicated in 4 blocks. A different nitrogenous fertilizer was used in each block. In September 1950, a colour assessment was made by visual scoring, ranging from 1 for a yellow and moribund condition to 10 for a vigorous blue-green appearance. At the same time the season's height growth was measured. There were no differences in growth, but the effect of the nitrogen on the colour of the shoots was most marked. The same assessment was repeated 1 year later. It was then found that the colour differences in favour of nitrogen had continued in the second year, and had caused an obvious increase in growth. The average increase in shoot growth per plot in the 8 plots receiving nitrogen, as compared with the 8 plots without nitrogen, was 0·40 foot. There were no significant differences between the results of the various forms of nitrogen used. Statistically, the response to nitrogen was very highly significant ($P<0{\cdot}001$). There was little increase in growth in response to the application of phosphate. (Average increase in the 8 plots receiving phosphate over the 8 plots without phosphate = 0·08 feet.)

	First season		*Second season*	
	Mean colour score	*Mean growth in feet*	*Mean colour score*	*Mean growth in feet*
Control	3	0·25	5	0·18
Nitrogen alone	6	0·25	8	0·52
Phosphate alone	3	0·20	5	0·20
Nitrogen and phosphate combined	6	0·25	8	0·65

The direct value of the results obtained from these experiments depends on whether economic methods of heather suppression can be evolved. Neither mulching nor hand-hoeing fulfils this requirement. Mechanical rotary hoeing depends too much on a level forest floor. The solution may lie in mixtures with a shade-casting species such as Japanese larch in belts wide enough to allow adequate rooting by the heather-sensitive species, and mixtures of the multiple-row type are being tried experimentally. The earliest of these, planted in 1943, are responding in the manner expected, though further time must elapse before the full implications of the method can be assessed. The manurial experiment at Broxa is too young to be used as anything more than a pointer towards the alleviation of check in Sitka spruce, but has opened up a new line of investigation.

ACKNOWLEDGEMENTS

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NATURAL REGENERATION OF PINE AND BIRCH ON THE HEATHER MOORS OF NORTH-EAST YORKSHIRE

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SUMMARY

Both pine (*Pinus sylvestris* L.) and birch (*Betula pubescens* Ehrh.) usually invade after a fire, the invasion reaching greatest force after 3 to 5 years, then falling off rapidly probably with the return of the heather (*Calluna*). Pine seedlings only grow vigorously if their tap-roots reach the pan, when secondary roots are developed extensively. In birch the tap-root is not well developed, but secondary roots spread vigorously sending down sinkers to penetrate the pan. Regeneration of birch is helped by rotten stumps and roots which its mycorrhizal roots explore. The root forms are compared and contrasted and the findings compared with the work of Laitakari and Erteld.

THE studies reported here are part of a much wider survey of the ecology of the moors on the sandstone-capped Tabular Hills of north-east Yorkshire. These moors offer many problems in afforestation, yet given adequate fire protection and seed supply, trees will establish themselves sub-spontaneously and can give reasonable subsequent growth, at any rate in the early stages. More information was sought about the conditions favouring natural regeneration on the strongly podzolized heather-covered soils, and to this end attention was mainly directed to the moors on the Hackness outlier, namely Hackness, Silpho, and Suffield moors. These inquiries were made during 1948–9; much of the material studied has now been destroyed to make way for new plantations.

The most important colonizers of the moors are Scots pine and birch. It can be assumed throughout what follows that the species of birch referred to is *B. pubescens*. *B. pendula* is only found occasionally. Where it does occur, however, it shows better growth than *B. pubescens*. Oak (*Quercus* spp.), rowan (*Sorbus aucuparia* L.), and willows (*Salix* spp.) are the only other woody species, but they are restricted to certain habitats and cannot be regarded as colonizers of the open moor. They will not be dealt with here.

The distribution of natural regeneration of both pine and birch is localized and depends very much on the relation between seed-trees and wind direction. There is a noticeable contrast between the eastern stretch of Suffield moor, which shows abundant regeneration, and the Hackness and Silpho moors which are almost barren of seedlings (see Fig. 1). This has given rise to the impression that Suffield moor is more fertile, but there is no reason to believe that the difference is other than one of orientation in relation to seed-trees. In the case of pine these have arisen probably as self-sown stock from a plantation made on West Suffield moor round about 1800, though this plantation no longer exists as such and the area is now *Callunetum* with scattered stunted pine. Along the road, however, the pine has grown better and has given closed canopy, and this belt forms the main source

of seed for the eastern stretch of Suffield moor. Birch has also established itself along this road, doubtless having seeded in from the daleheads.

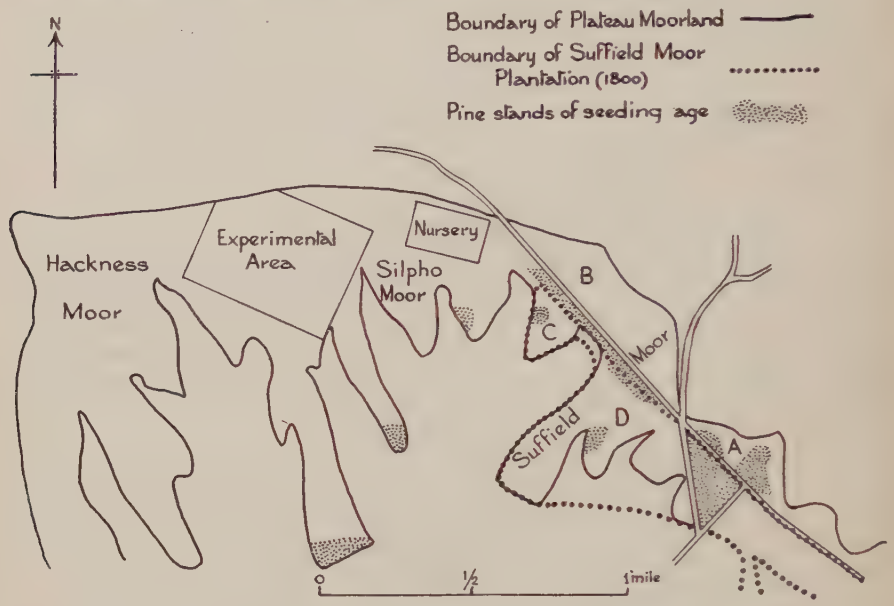

Fig. 1. Map of the plateau moorlands on the Hackness outlier.

The difference in mobility of the seed of pine and birch is well seen on these flat, exposed plateaux. In general pine stocking falls off markedly beyond 80–100 yards from the parent tree, whilst with birch about 300 yards would be a comparable figure. There is no doubt that birch seed is carried much greater distances, but the seeding intensity seems to be an important factor in determining establishment. Whilst seedlings are found amongst the heather on Hackness moor, they are very scattered and often confined to local disturbances of the moor surface such as old cart-tracks. Yet in the cultivated experimental area, birch is establishing itself freely, showing that the seed is reaching even the more remote parts of the moor. Only where the heather dominance is broken is the seeding intensity sufficient to allow establishment. The reasons for this have not been investigated.

SCOTS PINE

Although at the time these studies were made regeneration of Scots pine was quite widespread on the eastern side of the moors, it was not easy to find areas of sufficient size and uniformity to investigate closely. Altogether only four suitable areas were found and even these were not sufficiently extensive to allow adequate statistical treatment. These areas, A to D, are shown in Fig. 1.

In any one of these there was a wide range of seedling size, from a few inches to several feet in height, suggesting that continuous establishment was taking place. However, when the age of the seedlings was estimated by branch whorls it was

found that the ages of all the seedlings fell within certain narrow limits. This is illustrated for each of the four sites in the histograms in Fig. 2.

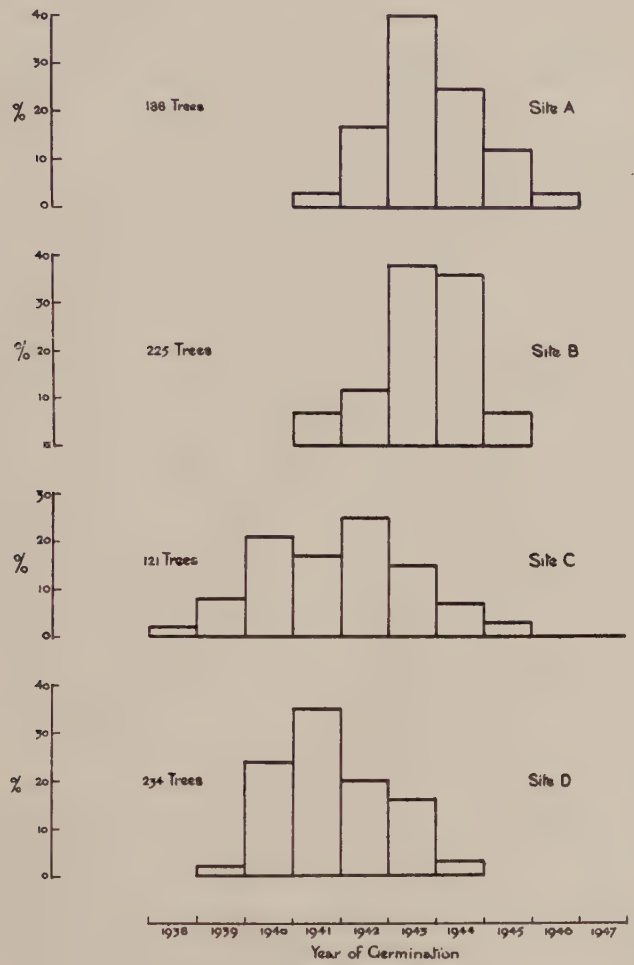

Fig. 2. Age distribution of pine seedlings.

It was realized that branch-whorl counts are rather unreliable, and to test the degree of error a sample of 50 trees was culled and sectioned for ring counts. This method also has its limitations, of course, but the errors are likely to be less than by whorl counts. This test could not be carried out on sufficiently large a sample to allow a statistical correction to be applied, but it showed that there was a slight tendency in whorl counts to overestimate the age of young seedlings, and to underestimate the age of older seedlings. Correct estimates were obtained in 40 per cent. of the samples and 90 per cent. were within 1 year of the age shown by ring counts. The result of this test shows that, though there are errors in the

percentages represented in Fig. 2, they are not large enough to affect the general conclusion that each stand has narrow age limits.

Normally regeneration only takes place after some disturbance of the *Callunetum*, usually a fire, and there is little doubt that these histograms are directly related to the last fire on each site. Exhaustive local inquiries have failed to reveal the date of the last fires. Sites C and D both had seedlings which germinated in 1939, and on site C even in 1938. This contrasts with sites A and B, where the oldest seedlings only dated back to 1941. Only for site C is there any additional evidence of the date of the fire; this comes from a 42-year-old oak which survived, but callus wood over a fire scar showed a ring count in April 1949 of 12, indicating that the fire was either in the autumn of 1936 or the spring of 1937. There was therefore a gap of a year before any seedlings appeared on site C after it had been burned, and when they did so the numbers were very small. The general form of all the histograms shows that regeneration is poor immediately following a fire, but that it gradually builds up until a maximum is reached 3–5 years afterwards. That this should be so is perhaps surprising in view of the fact that there would be a temporary increase in available mineral nutrients after burning, and the heather vigour would be at its lowest ebb. No entirely convincing reason has yet been found to account for the observed facts; the most likely appears to be the effect of either high summer temperatures or frost in winter on young seedlings unprotected by a vegetation cover.

The decrease in regeneration after the maximum has been reached is more easily accounted for, almost certainly being due to the return of the heather. This can readily be shown by studying the age distribution of natural regeneration coming in on newly ploughed rides between plantations of seeding age. In the year following ploughing the establishment of seedlings is greatest, and rapidly drops until it ceases altogether after 3 or 4 years; by this time the heather is in complete control again.

It might be suggested that seed-years of different virility may account for the forms of the histograms, but looking at all the curves together it is seen that high values (20 per cent. or more) occurred in every year from 1940 to 1944, whilst some seeding is recorded over a continuous period of 10 years. There is no reason to believe, therefore, that differences in seed years are responsible for more than minor variations.

Of the four sites studied, three of them have very similar histograms, with a marked peak and a spread of only 5 or 6 years. Site C, on the other hand, has a spread of 10 years and no clear-cut peak; regeneration is vigorous over 4 years. This suggests that the onset of inhibition of regeneration by heather is delayed, a conclusion which receives some indirect support from other features of the site. Intensive mapping of this site has revealed a large number of old stumps signifying constant occupation of the ground by trees, probably since the original planting 150 years ago. Under these conditions heather may not have resumed complete control since the area was planted. Frequent patches of *Vaccinium myrtillus* L. now dying through exposure to light bear out the conclusion that there has been a denser tree-crop than there is now. The succession of tree roots

in the soil would considerably modify the soil profile physically, and evidence will be produced later to suggest that this can favour the development of a subsequent tree-crop. Site C is the only one of the four sites with vigorous birch regeneration and this may contribute to the breaking of the dominance of *Calluna* as that species is intolerant of shade and is certainly locally weakened. The influence of regular supplies of birch litter to the soil may also be of some significance.

On site C, therefore, it seems likely that the recent history may have improved the site as a habitat for natural regeneration as well as reducing the dominance of *Calluna*. But even though the inhibitory effect of *Calluna* on pine regeneration may have been delayed and modified, it should be noticed that the other end of the histogram still exhibits the weak regeneration immediately after fire, which confirms that this influence is a direct result of fire itself and is not just a function of the habitat.

The cessation of regeneration as heather returns does not appear to be due to above-ground competition, for regeneration may have ceased even where the *Calluna* is not itself in continuous canopy, as on site A. Here the *Calluna* was short and there were many patches of bare raw humus uncolonized by pine seedlings. This focused attention on underground factors, and particularly on the root systems of the seedlings. Two of the sites showed a marked contrast in the vigour of regeneration; on D it was vigorous and healthy, whilst on A, though younger, the seedlings were stunted and frequently diseased. Roots of typical seedlings were completely excavated on each site.

Healthy seedlings on site D showed a very characteristic root form. The main laterals were all concentrated in, or immediately beneath, the *Calluna* raw humus, and were very long and almost unbranched. On a seedling whose total height was only 25 inches, surface roots over 7 feet long were recorded. There were few fibrous rootlets arising from these roots and none appeared to be mycorrhizal. The tap-root was persistent and stout, and reached but did not penetrate the iron pan. At the B horizon it produced a brush-like ending of small roots. One or two small secondaries were given off in the leached horizon. No other roots in the whole system penetrate the leached layer, except very occasionally a vertical sinker arising some distance out along a main superficial root. In these investigations only one pine was recorded rooting below the iron pan.

The root form of the stunted seedlings on site A showed a marked contrast. The extensive system of surface laterals was entirely lacking or represented merely by weakly fibrous rootlets a few inches long. The tap-root was also attenuated, and in no case did it reach the B horizon, but petered out in the leached layer.

The only apparent difference in the soil between these two sites was that the leached layer was thicker on site A (12 inches) than on site D (6 inches). This difference could only affect the tap-root, so the question was raised whether the reaching of the pan by the tap-root was necessary for the full development of root and shoot. To check this an examination was made of a healthy seedling on site A (only one could be found), and poor seedlings on site D. The former, though only a 3-year seedling, was very vigorous, and on excavation its tap-root was found to have reached the pan, which proved to be locally shallow; the laterals, too, were

showing exceptional vigour. Of the poor seedlings on site D, not one had reached the pan, but were growing where the pan was locally deeper, and their root systems as a whole were very similar to those of the unhealthy seedlings on site A.

These observations confirm the conclusion suggested above that a healthy seedling is one whose tap-root has reached the pan whereas one which does not achieve this is likely to fail. This means that pine regeneration on these moors is favoured by a shallow soil profile, a factor which may well restrict the growth in later life. That this happens can be seen from the scattered older trees which show the conical trunk indicative of a rapid fall in the rate of growth, and which are particularly prone to windthrow. It is a further example of the well-known fact that successful regeneration does not imply the suitability of the site for that species.

To establish just what advantage is conferred on a seedling by reaching the pan is a physiological problem which has not been pursued. It was very noticeable at the time of the investigation (June 1948) that though the upper layers of the soil were becoming dried out, at pan level the soil was very wet. The humus layer and dead roots (*Calluna*) above the pan were acting as a sponge and water could be squeezed out. It is uncertain to what extent pine and heather roots are in competition at this level, but it probably varies with season. *Calluna* is notably intolerant of waterlogging, and the wet conditions in the leached layer and at pan level in winter and spring probably restrict its activity here to the drier summer months. These fine deep-going roots of *Calluna* are probably produced afresh each year as conditions become favourable. In contrast, the pine tap-root is a permanent organ, and though it does not appear to be in its most congenial environment, it is in a position to take advantage of suitable conditions each spring as soon as they occur, well in advance of competition from *Calluna*. This may account for the comparative success of pine seedlings in withstanding heather competition in contrast to shallow-rooted species such as spruce (*Picea* spp.).

This argument would apply not only to the absorption of water but also of nutrients, if in fact any are available at pan level. That microbiological breakdown is not vigorous is indicated by the layer of almost pure organic matter just above the pan, which is characteristic of these soils. Nevertheless, the roots may be able to obtain some nutrients which are deficient in the upper soil layers. It is usually found that the pine roots running at pan level are flattened and adpressed to the surface of the pan.

To conclude, the reaching of the pan by the pine tap-root confers on the seedling some advantage in its competition with the heather, and as a result both shoot growth and lateral root extension are stimulated. Once this is achieved, the seedling is able to maintain its growth against the full competition of the reinstated heather.

BIRCH

Birch does not lend itself to a study of age distribution as does pine, owing to its irregular branch form and a tendency to produce false annual rings. Nevertheless, observations show that naturally regenerated stands on these moors are almost

even-aged, within a range of about 8 years. Whether birch suffers from an inhibitory factor after the moor has been burned is not known, but there is little doubt that its regeneration is stopped by the return of the heather. It is doubtful whether birch can invade dense *Callunetum*, but if the competing vegetation is destroyed, usually by fire, the seedlings will establish themselves given adequate seed supply.

Whilst regeneration is most vigorous on the site of a previous tree-crop (e.g. site C already described), it will also invade moorland of long standing up to about 300 yards from a prolific seed source. In doing so, the density of stocking decreases evenly with the distance from the seed source. This contrasts with the distribution on a site which has previously carried trees. Here the distribution can be shown to exhibit a marked grouping (Fig. 3).

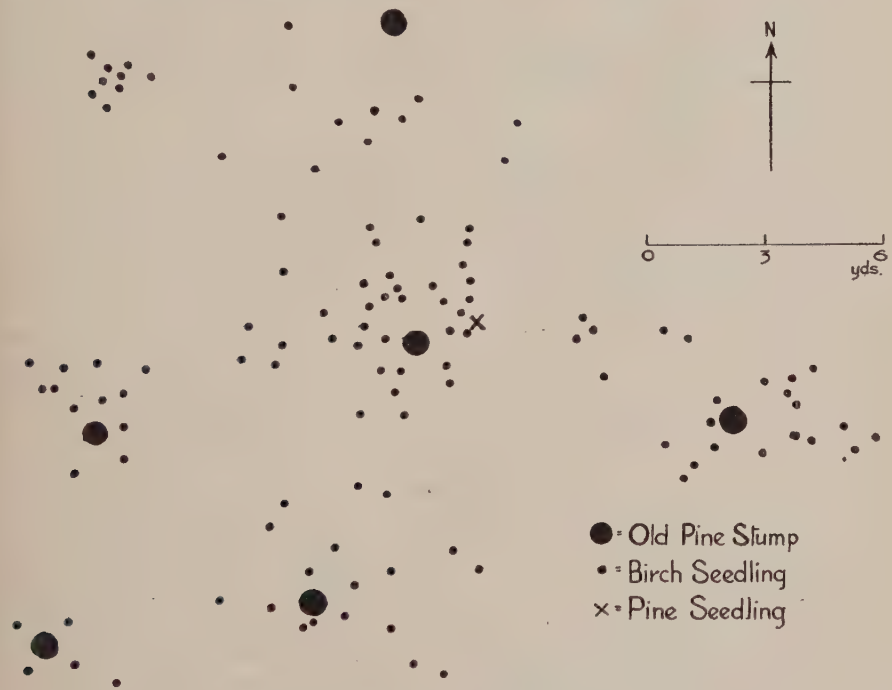

Fig. 3. Grouping of birch regeneration around old pine stumps.

Such an area was studied in detail. It was soon established that each group of birch was centred on an old pine-stump. Most stumps were completely covered over with *Calluna* raw humus and it was impossible to estimate either the age of the trees or how long they had been dead, though presumably they originated directly or indirectly from the plantation of about A.D. 1800. Whether they were cut or destroyed by fire was also debatable, but the irregular state of preservation of the stumps suggested the latter. It seems likely that the stand was open, presumably with heath between the trees, as indicated by the lack of such plants as *Vaccinium* which are found where the canopy has been denser.

A transect through one of these groups shows that the largest birches—6–8 feet high—are at the centre of the group, and that the height falls to less than a foot on the edge. The larger trees, 7–10 years old, were sufficiently tall and dense to shade out the heather and allow the entry of *Deschampsia flexuosa* (L.) Trin. in the centre of each group.

The first point investigated was whether the small trees on the fringe of the group were younger than those in the centre. It was found that the age distribution was similar for trees of all sizes, and the stand as a whole was relatively even-aged. There must be some strong factor at work to account for one tree, 8 years of age, being only a foot high whilst another of the same age is 7 feet high. Once more it was obvious that above-ground competition was not responsible.

In Fig. 3 there is seen a tendency for the seedlings to exhibit a radial alignment centred on the old stump. This might suggest some connexion with the old root system of the pine stump. Such a system was selected for detailed investigation.

It was interesting that this radial tendency was emphasized by the direction of the main surface roots, which sometimes ran from tree to tree so directly that it looked superficially as though the centre trees were producing runners. But each root, when reaching the stem of the adjacent tree, looped round it and continued its course. Three trenches at different distances from the centre were cut down to the subsoil across one of these lines of trees; the six faces of these three trenches are illustrated semidiagrammatically in pairs in Fig. 4, all drawn as though looking towards the stump.

The humus 'pockets' seen in each face are obviously sections of a continuous humus channel; this was confirmed in a radial trench. Such humus channels are frequently met with in these moorland profiles, particularly in the subsoil, and even in places where there has been no tree growth for centuries. They are undoubtedly old root channels, and very large ones may be hollow. In the present case the channel was not proved to originate from the rotten stump, and there remains the possibility that the pine was growing on the site of a very much older tree. No evidence of more recent roots was seen, however, in these sections, and it should be noted that wood loses its character quickly in these soils. Old stumps are riddled with fungi and such animals as wood-ants, and centipedes are frequently found in the decaying timber. A black organic residue produced by this destruction may apparently remain in the soil for very long periods.

Though not all the birch roots entered these humus channels, some certainly did, and in the course of many root excavations of birch, it has been found that the exploitation of rotten stumps or roots is frequently to be correlated with vigorous growth of the tree. The degree of decay of the wood is a factor of some significance. Unless the old roots are sufficiently decayed, the birch roots merely grow underneath them, closely adpressed, and sending occasional clusters of mycorrhizal rootlets into the bark. When the dead roots are softer, however, the birch roots will enter the rotting wood and follow the old roots for many feet, producing dense masses of mycorrhizal rootlets. In an advanced stage, the dead root may consist merely of a shell of bark stuffed with mycorrhizal rootlets, with the main birch roots threading lengthwise through the whole mass. The stumps

on the moor are nearly all pine, but there is evidence that hardwood material may be exploited in the same way.

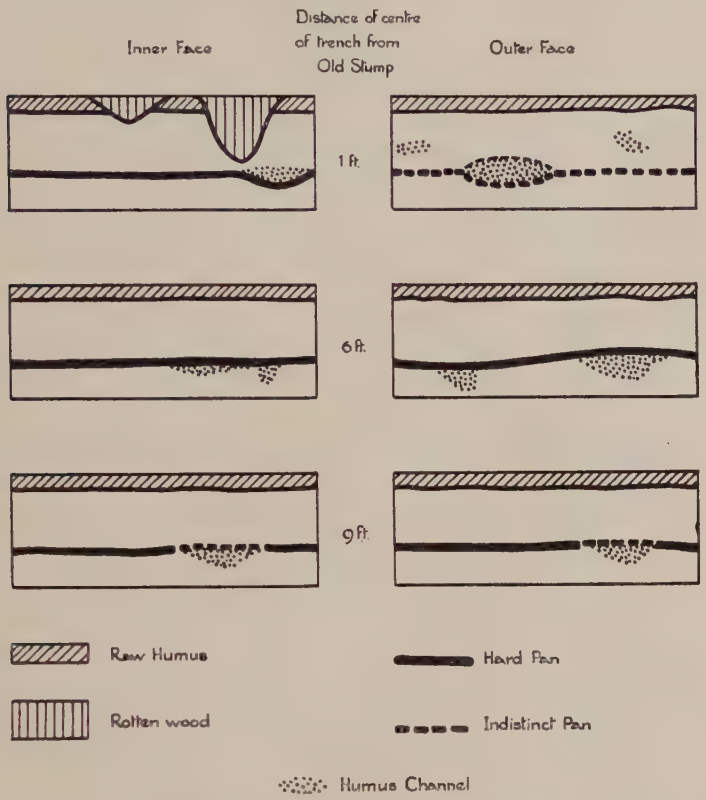

Fig. 4. Section diagrams of three trenches cut across a line of seedling birch.

The general form of the root system developed by birch on these soils differs in several respects from that of pine (see Table I). The tap-root is usually poorly developed, often abortive. Long surface runners are produced at an early stage, and these give rise to vertical sinkers at intervals. In a healthy birch it has been observed that there is always one or more (usually four or five) of these sinkers penetrating the pan and reaching the subsoil, though just as many fail to do so. Particular attention has been paid to this penetration of the iron pan by birch sinkers. One can never be absolutely sure that initial penetration is not through a small fault in the indurated layer, but careful excavation of many examples gives no reason to believe that special circumstances are prerequisite. Penetration is not usually direct; the roots turn along the pan when they first reach it and eventually penetrate obliquely. On reaching the orange sand beneath they frequently produce fibrous branchlets, contrasting with the simple form above the pan.

The exploitation of the C horizon appears to be associated with the vigorous growth of birch on these soils, and it is noteworthy that the small trees on the

outskirts of the regeneration groups frequently had only a superficial root system. What it is that enables the tree to put down sinkers is not known, but there may well be some connexion here with the rooting in rotten wood. It must not be supposed, however, that deep rooting is impossible without the exploitation of rotten wood; it certainly does occur on moor which has been treeless for centuries, though the number of vigorous trees per unit area will be much smaller. It might be noteworthy here that mycorrhizal clusters have occasionally been seen in the humus layer which sometimes develops strongly just above the pan.

To conclude this section a suggested outline is given of the establishment of birch in the group pattern. After the *Calluna* has been temporarily suppressed by fire, seeding-in takes place and the seedlings are able to live free of competition for several years. As the heather returns, so competition becomes fiercer, more so than for pine as birch may lose its tap-root very early and be entirely surface rooting, thus competing directly with the heather. At this stage the utilization of a mass of old wood in the soil may endow the birch with certain resources of water and nutrients which are not tapped by the *Calluna*. The role of mycorrhiza here is interesting; exactly what happens to the root-inhabiting fungi of the pine when it dies is not yet known. The recent observations of Garrett (4) suggest that mycorrhizal fungi are probably only able to live as saprophytes in competition with soil-inhabiting fungi for a relatively short period. The length of this period will depend on the vigour of other species able to survive under existing conditions, and as these soils may inhibit many of the normally occurring woodland saprophytes, it is possible that the mycorrhizal fungi may persist in these rotten stumps for longer than one might expect. If some of the mycorrhizal associates of pine can also enter into symbiosis with birch, we may see these old stumps as islands of living mycorrhizal fungi surrounded by a soil devoid of such fungi. It has been suggested that *Boletus scaber* and *Amanita muscaria* may be common to both trees; fructifications of the former are abundant in the regeneration groups, whilst the latter is also occasionally found. It is interesting that my colleague, Dr. W. R. C. Handley, has found that only two mycorrhizal fungi of those so far tested are able to grow in a medium containing *Calluna* peat extract. One of these is *Boletus scaber* (the other *Rhizopogon luteolus*); *Amanita muscaria*, however, did not grow (unpublished). If there is some such mutual relationship between the symbionts of birch and pine, it is understandable that the young birch roots reaching the sphere of influence of an old stump may encounter their fungal partners early in life, which under these conditions must be deemed advantageous. The formation of large mycorrhizal clusters in rotting woody tissues shows that this substrate continues as the main sphere of activity in preference to the organic horizons of the surrounding heath soil. Those seedlings near a stump will therefore be more favoured than those condemned to operate only in the heath soil, in direct competition with *Calluna*.

It is reasonable that those nearest the stump itself, having a larger volume of rotting wood to support them than those connected only with the tapering pine roots at the periphery, will remain relatively independent of the heath soil for a longer period and therefore should show superior growth. This will enable them

more effectively to shade out the *Calluna* and so remove their main competitor. Being better established they are also more likely to penetrate the pan with sinkers, thus reaching a richer supply of mineral nutrients and a more constant water reserve (Dimbleby, 1). Under such conditions birch has a unique advantage over all other moorland invaders.

THE MOORLAND PODZOL AS A ROOTING MEDIUM FOR PINE AND BIRCH

A comparison of the observations recorded here with those of Laitakari (5, 6) and Erteld (3) in Finnish forests and German plantations respectively shows that whilst there are very close parallels in root behaviour, especially in the case of birch, there are also some interesting points of difference. Both these authors record the more profuse fine rooting of birch and the greater average depth of birch roots in comparison with pine, whilst Erteld's diagrams of the origin of sinkers from horizontal birch roots might have been taken from the moorland material. But the simple, attenuated root systems of pine on the moorlands contrast strongly with the descriptions of much more vigorous and varied systems in the Finnish forests. There deep-going sinkers arise frequently from horizontal roots; on the moorlands they are exceptional. The presence of old stumps and root channels in the forest habitat stimulates the production of sinkers, whereas on the moors such conditions, when they occur, do not influence the roots of pine; birch, however, will take advantage of them. Both these authors were dealing with trees much older than those described in this paper, but even so Laitakari associated regeneration of pine with old stumps, though he did not mention the same phenomenon for birch. On the moors the grouping of birch around old stumps has been described, but pine showed no such tendency. The vigorous mycorrhiza of birch under these conditions contrasts with the absence of mycorrhiza in the moorland pine, yet another point of difference from the pine in Finnish forests.

These comparisons suggest that soil conditions on the moorlands are, by the standards of the Finnish forests, poor to the extent of being limiting for the adequate root development of pine, though birch can still compete successfully, particularly if there are the remains of a previous tree crop. It seems likely that this poor state of the soil is directly connected with soil microbiology and through this with the nutritional status of these podzols. Other factors must also play a part; in particular the disappearance of old tree-root channels from what is now a compacted sand must have had an adverse effect on soil aeration and drainage. Laitakari believes this to be the reason for poor tree-growth on old agricultural soils as compared with forest soils of similar origin.

In Table I Laitakari's classification of the root system has been used as a basis for a comparison between pine and birch on the moorland soils. From these observations and from what has been said above, a conclusion of some practical importance would seem to emerge. In the early seedling stage the persistence of the pine tap-root confers upon that species a greater competitive power than the birch has; the frequently observed failure of birch in the first year or two is doubtless a reflection of its dependence upon its shallow root system. But once birch is established with a system of deep sinkers reaching the subsoil it is better

adapted to the physical, chemical, and microbiological limitations of this habitat than is the pine; and this apart from any consideration of the effects of the two species on the habitat as the stands develop (Dimbleby, 2).

TABLE I. *Summary of differences between root systems of pine and birch*

Surface root system	*Pine*	*Birch*
(*a*) Origin	Laterals only develop extensively if tap-root reaches pan.	Laterals develop at earliest stage, irrespective of tap-root.
(*b*) Depth	In lower part of raw humus.	In A_1 horizon or at junction of peat and mineral soil.
Deep root system		
(*a*) Tap-root	Persistent, cannot penetrate iron pan.	Abortive.
(*b*) Inner vertical root system.	None—apart from tap-root.	Consists of several sinkers of which one or two medium ones may penetrate the iron pan.
(*c*) Outer vertical root system.	Usually none. Occasionally a small sinker reaches but does not penetrate the iron pan.	Consists of scattered sinkers of small or medium size, several of which may penetrate the iron pan.
(*d*) Mode of formation of sinkers.	Branch from a surface root grows downwards.	*Either* as for pine *or* the growing tip of a vigorous surface root may turn downwards and continue vertically.
Fine rooting		
(*a*) Fibrous roots	Very few, mainly from tap-root.	Vigorous, mainly from smaller surface roots and from deep roots in subsoil.
(*b*) Mycorrhiza.	None observed.	Occasional in peat and humus pockets but very vigorous in rotten wood.

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(4) Garrett, S. D.: 'Ecology of the Root Inhabiting Fungi.' *Biol. Rev.* xxv. 220–54 (1950).
(5) Laitakari, E.: 'The Root System of Pine.' *Act. Forest. Fenn.* xxxiii. 1–380 (1929).
(6) —— 'The Root System of Birch.' Ibid. xli. 1–216 (1935).

CORRIGENDA. A FALLACY IN THE THEORY OF GROWING STOCK BY R. BOURNE

NOTE BY THE EDITOR

WE are indebted to Mr. W. M. McNeill for calling attention to certain obscurities and inaccuracies in the text and in the figures of the paper 'A Fallacy in the Theory of Growing Stock', by R. Bourne, which was published in vol. xxiv, No. 1, and in the figures of the table published in vol. xxiv, No. 2, under the same title. We are also indebted to Messrs. C. W. Scott and M. J. Penistan, who with Mr. McNeill examined these defects and suggested the publication of the correction list below. Circumstances made the preparation of the paper more than ordinarily difficult, and we take the opportunity thus afforded to set right certain errors which did regrettably creep in in spite of the care taken. The same number of additional copies of the correction list is being printed as was printed of the paper and the table, and these will be sent free to the same addresses as before.

Forestry, Vol. XXIV, No. 1

P. 11, line 19: Delete the word 'age'. The sentence would then read as follows: 'In selection forests the growing stock is assessed by size and number of stems, not by the area occupied by each age irrespective of size.'

P. 12, Fig. 1: Insert after 'Percentage' the word 'volume'. The description of Fig. 1 would then read as follows: 'Percentage volume distribution of the ideal total growing stock, &c.'

P. 15, Fig. 4: The figures of volume by size classes do not in all cases agree with the data published as an appendix in *Forestry*, vol. xxiv, No. 2, pp. 159–61. The volumes in cubic feet per acre for the three woods, as corrected from the published figures, are given below, the figures in brackets are those appearing in the original Fig. 4.

Moor End Wood

Year	*1924*		*1931*		*1945*	
Vol./ac. by size classes	257 (257) 272 (272)	727 (737)	91 (91) 646 (646) (1037)	1037	99 (100) (1500)	465 (464) 1497

Coachway

Year	*1924*		*1931*		*1945*	
Vol./ac. by size classes	426 (426) 527 (527)	1124 (1120)	210 (204) 837 (835)	857 (860)	122 (121) 1106 (1100)	736 (739)

Bottom Wood

Year	*1924*		*1931*		*1945*	
Vol./ac. by size classes	307 (309) 671 (671)	925 (930)	229 (228) 737 (738)	844 (844)	180 (180) 908 (905)	516 (508)

P. 16, line 16: Delete full stop and add the words 'but grown as evenaged crops'. The sentence would then read as follows: 'In addition to the ideal . . . but grown as evenaged crops.'

Forestry, Vol. XXIV, No. 2

Pp. 159–61: Appendix. There are some errors in the calculations of the Periodic mean annual increment per cent. and per acre. The corrected figures are given below; the figures in brackets are those appearing in the original appendix.

Moor End Wood			
Periodic mean annual increment per cent.	9·5	2·76	5·7
Do. per acre	119 (115)	49	72
Coachway			
Periodic mean annual increment per cent.	0·24 (1·7)	2·6	1·6 (1·7)
Do. per acre	5 (4)	49 (42)	34
Bottom Wood			
Periodic mean annual increment per cent.	1·3	2·85 (2·8)	2·25
Do. per acre	25	52 (51)	43

GENERAL

It is not known from what sources the author obtained the data appearing in Fig. 2 and Fig. 3 of the original article. These data, though unexplained, can be assumed to have been taken from actual measurements and enumerations.

REVIEWS

A Preliminary Enquiry into the Influence of Solar Radiation on Insect Environment, with Special Reference to the Relation between Pest Epidemics and Fluctuation in Solar Radiation. W. B. R. Laidlaw. Transactions of the Society for British Entomology, Vol. II, Part 2, pp. 17–80. 31st October 1951. Price 7*s.* 6*d.* post free from the Secretary, 454 Christchurch Road, Bournemouth, Hants.

Review by R. Neil Chrystal

IN a short foreword to this very important survey of an exceedingly complex subject the author, having cited his chief sources of reference, adds the following preliminary comments. (i) He fully realizes that many of the research lines which his inquiry has suggested to him will prove difficult, expensive, and in many cases probably impossible to pursue at the present time, while much of the work will involve long-term team work spread over many years. (ii) He discounts the idea that solar or astronomical influence cannot be held in any way responsible for fluctuations in the populations of animals and plants, exerting some influence upon their state of health. His survey of the vast literature shows that he has much support for this belief. (iii) He feels, however, that if the ideas put forward in this paper should stimulate a desire for further inquiry, they will have fully achieved their object.

Study of the paper finds us in complete agreement with these remarks. It deserves critical study by all foresters whether they be specialists or not. It contains ideas for new aspects of forestry research necessitating the co-operation of the physicist, the forest biologist, and the forester. This research, however long-term it might prove to be, would probably in the long run have a profound effect upon forestry practice.

The paper is composed of five sections: 1. A general introduction dealing with the nature of solar radiation and its effects upon plant and animal life. 2. On the fluctuations occurring in solar radiation through sunspots, and their effect upon life. 3. On pest classification in relation to their radiation optimum conditions. 4. On the control and prevention of epidemics. 5. On suggested lines of future research.

In the first section, after a short account of the elementary physical facts relative to radiation, the discussion turns to the biological reactions to solar radiation, short and long wave. Discussing radiation optima in plants and animals, the author quotes the work of Graham in the U.S.A., on micro-climate in logs, as showing the effect of radiant heat upon the development of woodborers and bark-beetles, and also the researches of a number of authors showing the effects of increase or decrease of light on the production of the sexual and asexual generations in aphids. The question of ecological zoning according to conditions of radiation—i.e. the optimum amount of ultra-violet light radiation for any given plant species at any particular elevation—introduces some interesting observations on p. 30 on the effect on tree health and reaction to insect attack when an alpine species such as European larch is grown at lower elevations. This is followed by a consideration of the radiation-water link, and the optima for day and seasonal radiation.

In section 2 (pp. 34–44) the phenomena of fluctuation in solar radiation associated with sunspots are discussed. Data so far available show that epidemics, and certain physiological development stages, are influenced by sunspot cycles, the climatic conditions associated with these playing an important role. Warm, moist, conditions favour an increased development and population increase up to the sunspot (ultra-violet) peak, while cold, dry

conditions can reduce numbers quite suddenly through such factors as late or early frosts or seasonal drought. This discussion on the sunspot cycles, which can only be briefly referred to here, should be studied together with the diagrams illustrating the points relative to the occurrence and duration of cyclic pest outbreaks.

Section 3 (pp. 44–51) deals with pest classification according to optimum radiation conditions. Two main types of pest are recognized: A. Light-tolerant; B. Light-intolerant. The former are more important on account of their superior reaction to radiation influence, exhibiting recurrent epidemic tendency, and being highly responsive to periodic fluctuations in ultra-violet intensity through increase or decrease in sunspots. The defoliators are good examples of these. With the light-intolerant, or shade-dwelling species, the optimum for light and ultra-violet rays is much lower. Many aphids and adelgids, for example, find their optimum on shaded branches where, as often as not, there is a sap deficiency. This may be correlated with the fact that some of these insects apparently demand more protein than sugar in their diet, so that a situation offering them a high sugar content in the sap would be unfavourable. Here the author returns to the question already touched upon on p. 30, relative to the bad effect of bringing a tree species native to an environment with a high ultra-violet reception, and thus highly light-tolerant, and equally highly water-demanding, to a lower elevation where higher humidity reduces light and ultra-violet conditions below the normal optimum. In such a situation these factors combined with deficiency of soil water may bring the tree to a condition of sap reduction which will render it liable to the attacks of such insects as aphids and adelgids.

Where plant introductions to situations far removed from their light optimum produces liability to epidemic attack, climographic studies of their requirements in respect of ultra-violet, and/or sunlight, and water (seasonal or general) would help to eliminate the possibility of occurrence of such outbreaks. In section 5 (pp. 68–72) the author recommends acquiring plant records of a complete series of elevational contour-zones, with a light and ultra-violet intensity value for each, giving an index of the optimum of these for different species under varying conditions of aspect and other local factors. Such studies would have value in forecasting success or failure with a species introduced to a new environment.

In section 4 epidemics and their prevention are considered. The classification of the factor sequence set forth on p. 52 should be noted, and this is followed by a discussion of the complex action of solar radiation upon vegetation and pest, the influence of which may often be complementary. The last part of the section deals with applied controls based upon the operative factor. The use of artificial controls is examined and criticized. The ecological complex of natural woodland is then dealt with, and followed by consideration of artificial woodland conditions, their advantages and disadvantages, together with a discussion upon the silvicultural prevention of epidemics. In these pages basic suggestions are put forward as regards control, and these are in accord with the most modern conceptions of sound forestry practice.

The final section 5 deals with research fields. These are concerned, in the first place, with the question of forecasting outbreaks by means of data acquired by astronomical and physical means. The future possibilities of control by radiation are discussed, and certain lines of research suggested. The paper ends with some suggestions for biological experiment in the botanical and entomological fields. The author returns over some of the topics already discussed in an earlier portion of the paper, but more research data are considered here, and there are further diagrams illustrating ultra-violet and light ranges for species which might be subjects for experiment.

A paper of such wide compass as the present one cannot be adequately dealt with in such a brief review. Much has been, of necessity, omitted, but it is hoped that the value

of the author's work has been sufficiently demonstrated that readers will go to his own text and study it for themselves.

Silvicultural Systems. By R. S. Troup. Second edition, edited by E. W. Jones. Clarendon Press, 1952. Pp. 216. £1. 5*s*.

Review by H. R. Blanford

OF the several textbooks from the pen of R. S. Troup, *Silvicultural Systems* is probably the most useful and the most widely read. As the original edition was out of print, the Imperial Forestry Institute arranged for the publication of a second edition and its preparation was entrusted to E. W. Jones, Lecturer in Silviculture at the Institute.

Alterations in the original text have only been made where changes of practice and experience over the last 20 years have rendered them necessary. The most important deal with the Selection System, opinions on which have changed a good deal. It was felt that Troup himself would have wished to modify his original views and would certainly no longer have accepted the idea that the selection system produces poor timber. Such amendments as have been made would, we feel convinced, have been fully approved by the original author.

In a final chapter Jones deals with 'Developments in the Last Twenty Years'. In Europe the change has not been so much in the development of new systems as in the use of such systems that are more suitable for the greatly increased stress on soil fertility and health of the crop, the irregular and mixed crops now favoured, greater flexibility in management, changing markets, and the growing importance of genetics in forestry.

In other parts of the world, especially in India, Burma, and Malaya, and more recently in some of the African colonies and in North America, the last 20 to 25 years have shown very great silvicultural progress. This progress was only beginning when Troup left India in 1920, though he was himself mainly responsible for its start. In these days when the necessity for systematic forest management is becoming even more widely recognized, and foresters are experimenting with silvicultural systems applied to new species and other climatic conditions, the success and failure of the first attempts at adaptation of European systems to other classes of forests are of the greatest importance. The brief summary of the work done outside Europe, while probably adequate for instructional purposes, would, we believe, have been of additional value to practising foresters if it had been written up by leading silviculturists who have been mainly responsible for this work during recent years.

A brief note on up-to-date experiments in adapting silvicultural systems to the forests of North America might have been added. The system of clean logging by patches, the size of which is controlled by the distance to which seed can be conveyed by wind, in Douglas-fir forest in British Columbia, seems to be sufficiently well established to merit notice. These are perhaps minor points and should not detract from the welcome to the new edition of this excellent textbook.

Forestry in Farm Management. By R. H. Westweld and Ralph H. Peck. Second edition. Revised by R. H. Westweld. London: Chapman & Hall, 1951. Price 40*s*. net.

Review by G. B. Ryle

THE farm woodlot may be so small that the spade and the mattock can be shared with the fields or it may be large enough to justify the erection of a maple sugar refinery.

With such a range of variation it is not surprising that this book has evolved itself merely into an elementary manual of American forestry and forest utilization. As such it falls just short of excellence, but where it falls short is in the enunciation of actual facts or of essential details where advice is given.

A chapter of twelve pages on the farm forest as an aid to 'wildlife' preservation is gaily achieved without a single reference to any individual species of beast, fowl, or lesser denizen, and this is perhaps typical of the successful evasion of precision throughout the whole book.

The Changing Wild Life of Britain. By H. L. Edlin. B. T. Batsford Ltd. London. 1952. Price 21*s.* net.

Review by Sir William L. Taylor

TO achieve a conspectus of the zoological and botanical mutations that have gone towards the present-day build-up of the wild life of Great Britain, including also animal life that is no longer wild, in the space of 179 pages is a noteworthy undertaking. The book is eminently readable and brings out clearly the effects of the impact of a rising population over the ages on the wild creatures (other than insects) and wild plants, and the influences exercised by new acclimatizations that have occurred from very early times: its compilation is obviously the result of wide and patient research. Although the introduction of animals new to the British fauna is now in some measure checked, new plants continue to establish themselves both by accident and design. As to birds, the author asks 'Can lost and vanishing birds return'. The answer is 'Why not', and the recent restoration of the avocet as a breeding-species is a case in point.

Mr. Edlin rightly underlines the hope that large-scale afforestation since 1919 will tend to afford sanctuary for native carnivores, such as the pine marten and polecat, the status of which has become precarious, and may induce some of the lost raptorial birds to return to their former homes. There are chapters on mammals; birds; fish, amphibians and reptiles; and on plants and trees. In his account of the new trees to secure a foothold in our woodlands, the author, as a forest officer, is on familiar ground, but in his chapter on 'The Monstrous Regiment of Weeds' we miss reference to bracken fern and the rose-bay willow herb, or fire-weed, as weeds of importance to the forester.

The book is full of information and anecdote and is printed and illustrated in the well-known Batsford style: the old-time woodcuts, however, are open to criticism as untrue to life. It will certainly help to bring home to the general reader the losses and gains in the wild life of the country-side, and the causes that have proved inimical to some species and an aid to others, processes that are still going on. But the lady's slipper orchid is happily not yet quite lost to the British List.

SOCIETY'S AND OTHER NEWS

ANNUAL GENERAL MEETING AND EXCURSION IN THE STEWARTRY OF KIRKCUDBRIGHT AND DUMFRIESSHIRE, 1952

THE Society met in Dumfries, where the Annual General Meeting was held on 23rd September. Seventy-two members enrolled for the excursion and about as many attended. Mr. W. E. Hiley presided throughout in the absence of Professor H. M. Steven and Mr. A. H. Gosling at the Sixth Commonwealth Forestry Conference at Ottawa. At the beginning of the Annual General Meeting members stood in silence to the memory of Sir John Sutherland and of Lord Robinson, both in their time Presidents of the Society, who had died since the Society last met.

The excursion, which must rank very high among Society's excursions for its silvicultural interest and for the skill with which it was presented, consisted in visits to private and State forests in the Stewartry of Kirkcudbright and in Dumfriesshire between the 23rd and the 25th September. This series of visits, besides affording an insight into the considerable past history and stability of forest management in south Scotland, gave a remarkable demonstration of the progress that can be made when all assets are used to the common advantage through the co-operation of owners of woodland, their managers, foresters, and workers, members of the Forestry Commission staff, and consultants. The main task of organizing the excursion rested on Mr. J. A. B. Macdonald, the Conservator South Scotland, and on Mr. M. J. Penistan, until lately the Private Woodlands Officer of the Commission in the area, and on his successor Mr. W. N. Gibson. Papers on developments in the area by Mr. Macdonald and by Mr. Penistan will be found elsewhere in this number. But a host of others helped not only in interest taken but in active participation, help, and hospitality. The Society thanks them all.

The following were visited: Shambellie Estate near New Abbey (Mr. A. McC. Stewart); Dalbeattie Forest (Forestry Commissioners); Kirkennan Estate near Dalbeattie (Major-General Aymer Maxwell); Munches Estate near Dalbeattie (Commander D. Herries Maxwell); Dalswinton Estate near Auldgirth (Dalswinton Estates Co.); Capenoch Estate near Penpont (Mr. John Gladstone); Forest of Ae and the new forest village (Forestry Commissioners); Buccleuch Estates near Canonbie, where one party visited Langholm Woods and one party Moorburnhead Plantations (His Grace the Duke of Buccleuch, K.T.); and lastly Castlemilk Estate near Lockerbie (Sir John Buchanan-Jardine, Bt.).

On the last evening of the meeting a discussion took place in Dumfries, the subject chosen for which was 'Irregular Forestry with special reference to Hardwoods'. The discussion was opened by Mr. J. E. Garfitt, whose paper on one aspect of this subject will be found on an earlier page in this number. Several members spoke and an interesting debate ensued.

HONOUR

THERE will be general satisfaction at the inclusion of the name of Mr. A. P. Long, O.B.E. in Her Majesty's Birthday Honours Lists. Mr. Long, who is Director of Forestry for Wales, Forestry Commission, is promoted C.B.E.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, 1952

The following papers on forest subjects were read at the meeting in Belfast in September 1952:

Mr. J. Pimlott (Chairman, Forestry Sub-section): 'The Progress of Afforestation in Northern Ireland'.

The Marquess of Hamilton: 'Estate Forestry in Northern Ireland'.

Professor Mark L. Anderson: 'Sustention and Maximum Benefits as Elements in Forest Policy'.

Mr. James Macdonald: 'Modern Nursery Technique'.

Mr. J. A. B. Macdonald: 'The Place of *Pinus contorta* in British Silviculture'.

Mr. E. J. Sherrard: 'Reclamation of Poor Peatland'.

Mr. T. R. Peace: 'Poplar Varieties and their Silvicultural Uses'.

Mr. J. W. L. Zehetmayr: 'Recent Work on the Problems of Moorland Afforestation'.

Mr. J. M. B. Brown: 'The Role of Indicator Plants in Moorland Afforestation'.

Mr. W. L. Gibson: 'Exotic Conifers and their Importance to Forestry in Northern Ireland and the West of Scotland'.

Mr. C. D. Deane: 'Vertebrate Fauna of Ulster Woodlands'.

Mr. F. P. Wareing: 'Reproductive Development in Scots Pine'.

Professor Anderson's paper is printed in this number by permission.

It is understood that the meeting in 1953 will be in Liverpool and the meeting in 1954 in Oxford.

LIST OF MEMBERS

The list of members that follows, which it is intended to print annually in the *Journal*, contains the names of all those who were on the roll on 1st October 1952, and is in the form used experimentally in the list issued with the circular calling for nominations in February 1952. The list has been compiled from the information available in the Society's records. Where no descriptive initials are given, this is due to lack of information, and members affected are asked to send the appropriate details to the Secretary now. Changes of address, description, &c., should be intimated to the Secretary as soon as they occur, so that the records may be up to date when each annual list is being prepared.

MR. C. W. SCOTT

Mr. C. W. Scott, who edited the *Journal* with such distinction from 1946 to 1950, has retired from the Forest Products Research Laboratory at Princes Risborough, and during the spring of 1952 visited Jugoslavia to advise on the setting up of research there. Since then, under the aegis of the Colonial Office, he has led a mission to the Caribbean to advise on forest utilization. In 1953, we understand, he goes to Santiago to take up the apppointment of Professor of Utilization there. We wish him every success and look forward to his return to Great Britain in due course.

LIST OF MEMBERS

OF THE

SOCIETY OF FORESTERS OF GREAT BRITAIN

AS AT 1 OCTOBER 1952

Explanatory Note:

F.C.	Forestry Commission.
F.P.R.L.	Forest Products Research Laboratory.
I.F.I.	Imperial Forestry Institute.
M. of A.	Ministry of Agriculture.
M. of A. (N.I.).	Ministry of Agriculture of Northern Ireland.
P.F.O.	Private Forestry Officer.
R.B.G. (Kew)	Royal Botanic Gardens, Kew.
R.B.G. (Edin.).	Royal Botanic Garden, Edinburgh.

FELLOWS

Ackers, C. P., of Huntley.
Adkin, B. C., Coll. of Estate Mangt.
Aitkins, A. E., Consultant.

Backhouse, G. W., F.C.
Ballance, G. F., F.C.
Barrington, C. A. J., F.C.
Beresford-Peirse, Sir Henry, Bt., F.C.
Best, F. C., F.C.
Blair, Sir James Hunter, of Blairquhan.
Blanford, H. R., I.F.S. (retired).
Bloomer, Leonard, Consultant.
Broadwood, R. G., F.C.
Brown, Gilbert, Estate Factor.
Brown, J. D.
Brown, Thomas, Consultant.
Burgess, F. G., M. of A. (N.I.).

Cameron, G. J., Head Forester.
Cartwright, K. St. G., F.P.R.L.
Chalk, Dr. Laurence, I.F.I.
Champion, Prof. H. G., I.F.I.
Connell, C. A., F.C.
Courthope, Baron (Honorary Fellow).
Cowan, Dr. J. M., R.B.G. (Edin.).
Cruickshank, Hector, F.C.
Currie, J. H., F.C.

Dallimore, William, R.B.G. (Kew) (retired).
Davey, Reginald, Consultant.
Day, W. R., I.F.I.
Denman, Dr. John.
De Uphaugh, F. E. B., F.C.
Dixon, E. E., F.C.
Dowson, Dr. W. J., Cambridge Univ.

Edlin, H. L., F.C.

Feaver, B. R., F.C.
Fergusson, D. C., Edinburgh Univ.
Finding, S. L.
Fisher, Dr. R. C., F.P.R.L.
Fitzherbert, J. T. L., F.C.
Foggie, Alistair, Gold Coast.
Fossey, R. E., F.C.

Fraser, Dr. G. K., Macaulay Inst.
Fraser, James, F.C.

Galloway, J. A.
Galloway, R. A. (Secretary).
Garfitt, J. E., Consultant.
Gibson, W. N., F.C.
Glover, Sir Harold, I.F.S. (retired).
Goodwin, J. F., F.C.
Gorrie, Dr. R. M., Ceylon.
Gosling, A. H., F.C.
Grant, David, F.C.
Guillebaud, W. H., F.C.

Hanson, H. S., F.C.
Harker, M. G., F.C.
Harrison, P. D.
Hide, R. H., P.F.O.
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Hodson, G. A., Consultant.
Hughes, J. H., Australia.
Hummel, F. C., F.C.

James, J. E., F.C.
James, N. D. G., Land Agent.
Jay, B. A.
Jones, E. Wynne, F.C.

Kitchingman, G. D., F.C.

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Le Sueur, A. D., Consultant.
Long, A. P., F.C.

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Macdonald, J. A. B., F.C.
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Marshall, R. C., Consultant.
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Mould, R. C. L., Consultant.

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